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VR

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HOW DREAMS
CAUSE HEART
ATTACKS

**WHY CATS
HATE WATER**

HOW TO
BECOME
A FOSSIL

THE LIFE
& DEATH
OF STARS



6 WAYS TO
BEAT THE ODDS
AND WIN BIG

HOW SNAKES CAN
SAVE US FROM
EARTHQUAKES

THE DRONE
YOU SIT INSIDE

THE MAN
WHO BECAME
A BADGER

THE BIGGEST EVER HUNT FOR ALIEN LIFE

INSIDE STEPHEN HAWKING'S \$100M
MISSION TO MAKE FIRST CONTACT

PLUS WHAT HAPPENS IF WE FIND EXTRATERRESTRIAL INTELLIGENCE?



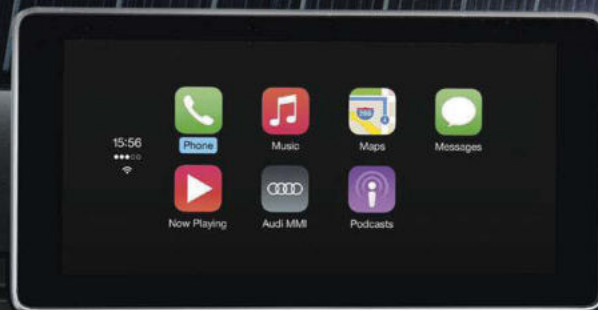
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Extra Urban 52.3 (5.4) – 83.1 (3.4) and Combined 44.8 (6.3) – 74.3 (3.8). CO₂ emissions: 144 – 99g/km. Images shown for 93/116/EEC. This allows a direct comparison between different manufacturer models but may not represent the actual fuel. More information is available on the Audi website at audi.co.uk and at dft.gov.uk/vca. The What Car? Car of the Year 2016 an A4 S line Saloon, available from £30,150 ROPR, with optional Matrix LED headlights (additional £650 RRP inc VAT), Driver



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WELCOME



Let me introduce you to the new *BBC Focus*. For the last six months we've been in the lab, experimenting on a new look. Like any good experiment, this process all began with some in-depth research. We met and talked to hundreds of our readers to rediscover what makes *BBC Focus* special, and interestingly, one word kept coming up: wonder.

Whether you want to know why the sky is blue or if we're alone in the Universe, curiosity is a lifelong passion. You want to know what makes the world tick and what it will look like in the future. Our job is to fuel that curiosity and reward it with dispatches from award-winning photographers and writers from around the world. In practice, I hope, the result is something that's new, but familiar.

What better place to begin this new era, then, than with one of the biggest questions of all: is there anyone out there? Stephen Hawking, Astronomer Royal Martin Rees and philanthropist Yuri Milner are hoping to answer this question with the most comprehensive search for alien intelligence yet. We investigate their plans on p34.

While astronomers look for alien worlds, I've been exploring virtual ones. Via a Samsung VR headset I've jumped out of a plane, visited North Korea and even been kidnapped. The last part wasn't much fun, but I'm convinced that, like smartphones and computers before it, VR is about to change everything. Find out more on p68.

And if you're still hungry for more, check out our brand new and improved website at sciencefocus.com

Daniel Bennett

Daniel Bennett, acting editor

IN THIS ISSUE



LORD MARTIN REES

Martin is the current Astronomer Royal, making him the perfect person to tell us what we should be looking for in our quest to find alien life. Read our interview with him in our cover feature. → p40



ROBIN INCE

Comedian Robin is a familiar voice on our radio, co-presenting *The Infinite Monkey Cage* with popular physicist Brian Cox. We're thrilled to welcome Robin to our pages as our newest *BBC Focus* columnist. → p51



JHENI OSMAN

Our new 'Science in the city' feature asks key scientists to share the best spots in their home city. Jheni, a keen traveller and science journalist, catches up with Cédric Villani in Lyon this month. → p106



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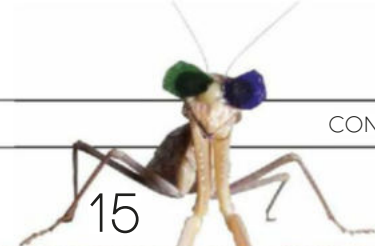


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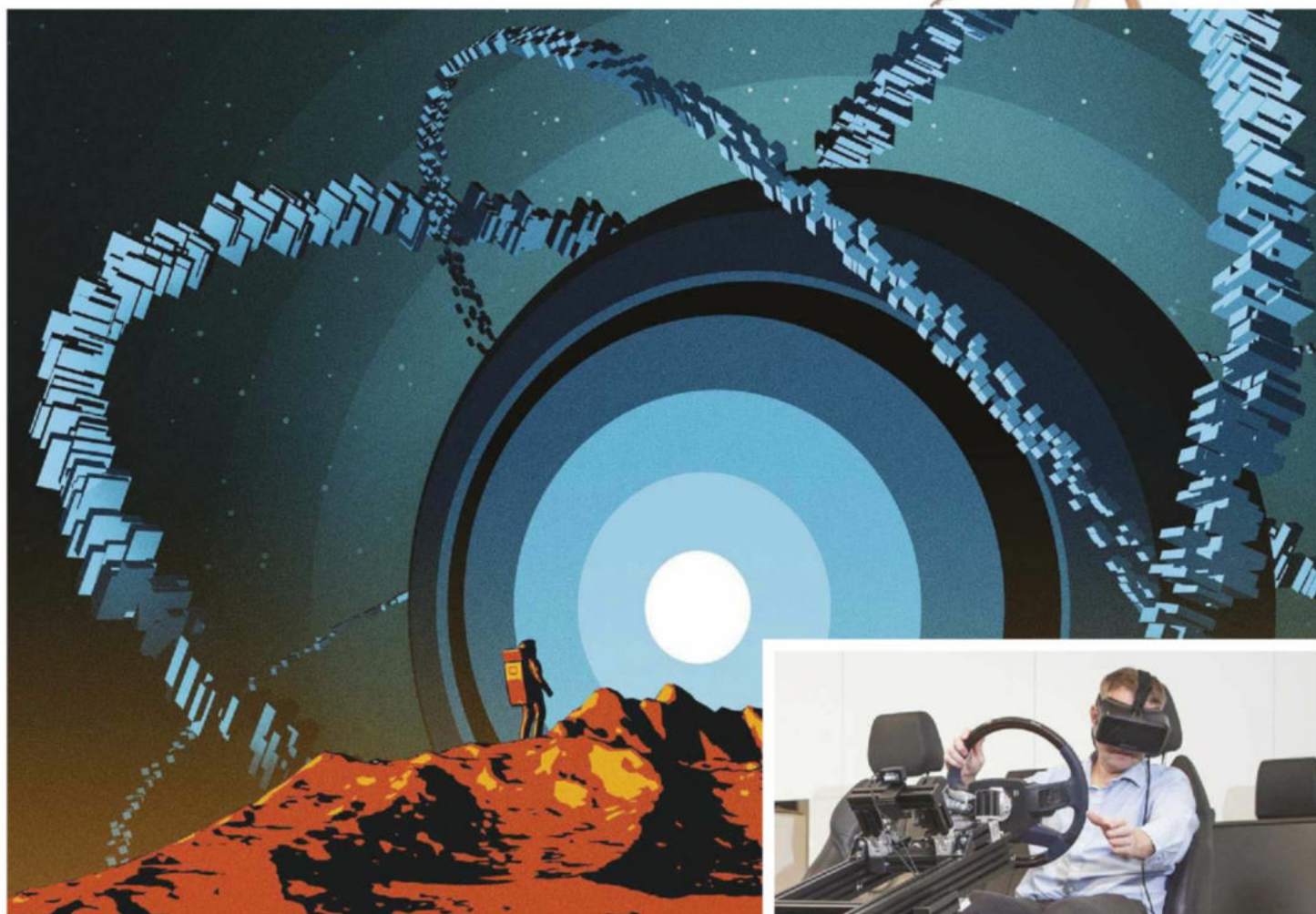


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At the heart of the image



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44 Where's the best place to look for new medicines? Surprisingly, it turns out the answer might be 'inside the fangs of a venomous snake'.

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52 Chance plays less of a role in all our lives than you might think. Discover how to beat the odds at the casino, and how to tell a genuine coincidence from a statistical inevitability.

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58 Animals have an uncanny ability to get out of the way before an earthquake or volcanic eruption. So could tracking their movements provide us with a natural early warning system?



44

Virtual reality gets real

68 A new generation of hardware is about to take VR out of the realm of niche gaming. Find out how all our lives are going to be affected by this most disruptive of technologies.

Are cookies addictive?

74 Can the obesity epidemic be explained in terms of addiction, or are 'chocoholics' simply making excuses? We look at the science.

Understand the life cycle of a star

94 In about five billion years or so, the Sun will swell into a red giant and destroy the Earth. But why will it do this – and how do we know?



94

Masked men

ASARO MUD MEN,
EASTERN HIGHLANDS PROVINCE,
PAPUA NEW GUINEA

Some of us may smear mud packs on our faces to improve our looks, but not these guys. Hailing from Goroka in the Eastern Highlands Province of Papua New Guinea, the Asaro mud men resemble something from a twisted nightmare.

The legend surrounding their appearance claims that when an enemy tribe attacked, they ran to the nearby Asaro River to hide. They waited until dark before emerging covered in thick mud, unaware that their attackers were still there. Upon seeing the eerie figures materialising from the darkness, the enemy tribe fled, believing them to be vengeful spirits.

Rumours spread that they were imbued with the supernatural powers of the river spirits, so the crafty elders decided to capitalise on this and created a new dress code for their warriors. To further the effect, they fashioned the clay into terrifying masks with exaggerated features studded with the teeth and tusks of wild boar.

In today's more peaceful times, the mud men's impressive displays are limited to scaring the wits out of paying tourists rather than neighbouring enemies.

PHOTO: GETTY



REPLY

Your opinions on science, technology and BBC Focus

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MESSAGE OF THE MONTH

A history lesson

I was surprised that 1932 did not get a mention in the 'Best of the rest' in your 2015 review of the year (Christmas, p32). In this momentous year, several significant discoveries were made in physics which contributed greatly to our understanding of the relationship between matter and energy and of the structure of the nucleus.

1932 saw the construction of one of the first particle accelerators by Irish physicist Ernest Walton and Englishman John Cockcroft, which they then used to bombard lithium nuclei with a beam of high-speed protons, thereby achieving the first artificial splitting of a nucleus, as well as verifying Einstein's famous $E=mc^2$ equation by experiment for the first time. In February, James Chadwick made his first observations of the latest sub-atomic particle to be discovered – the neutron. In August, the world of antimatter opened up when Carl Anderson discovered the positron.

These three great discoveries – combined with other achievements such as Kennedy and Thorndike's demonstration of time dilation and John von Neumann's work on quantum mechanics – show us that the 1930s weren't as dismal a decade as many seem to believe!

Kevin P McCarthy, Killarney, Ireland

➔ There were lots of years we could have chosen for that timeline. As you quite correctly point out, 1932 did indeed see several major breakthroughs in the world of physics, and could easily have warranted a mention on our timeline. But we were focusing mainly on years that saw big steps forward being taken in more than one scientific discipline, in keeping with the many varied breakthroughs in 2015 that the main body of the article was celebrating.

WRITE IN AND WIN!

The writer of next issue's *Message Of The Month* wins a small **EcoSphere pod, worth £99**. This fully enclosed, self-sustaining ecosystem uses technology from NASA to support tiny shrimps, algae and bacteria. You don't even need to feed it! For more information, visit eco-sphere.com



WORTH
£99



Sir John Cockcroft, pictured in 1935, a few years after his pioneering work splitting atomic nuclei

You spin me round

Stephen Baxter (Christmas, p29) discusses whether humans can reproduce in space and talks about how the lack of (or significantly reduced) gravity has been shown to negatively affect both sperm production and the growth of female ovaries.

Although this may be true, surely all it shows is that it's the lack of gravity that is the problem? By implication, this can be alleviated by spinning astronauts' working or living quarters at a proven rate that mitigates or even eliminates these effects. The reduced – but still significant – gravity on Mars or even the Moon may do just this. Of course, this requires a lot more experimentation and verification, but the idea of rotating these quarters is hardly new, having been

discussed decades ago in both sci-fi novels and scientific papers.

Radiation and high energy particle DNA damage may also be a problem, however.

Paul Bertenshaw, Ashby de la Zouch

Why green is seldom seen

I always find the articles written by Dr Helen Czerski in which she explains the science behind everyday stuff very interesting.

'Where are the green mammals?' (Christmas, p27) was the most recent. I suppose that most people who have pets like cats and dogs are aware these animals do not see colours as we do and, like me, just accept that fact without thinking about any practical issues that may arise from this.

The article reminded me that a while ago I saw an acquaintance of mine who hunts with a rifle. He was wearing a very garish disruptive pattern (camouflage) coat in various shades of orange and red, so I commented that surely the colour defeated the object of staying hidden. "Oh no," he replied. "The animals don't see the colour, this is so other hunters can see me!"

Obvious really, isn't it?

Ian K Parker, Devon

Dinosaur ditty

Your feature on earworms (Christmas, p59) really made me smile, particularly your art editor Joe Eden confessing to the *Jurassic Park* theme being his earworm nemesis. This catchy trumpeting theme is also the bane of both my and my colleagues' lives. It usually starts as a simple hum of just three

notes by any one of us while beavering away at work and, within moments, we are at loggerheads as to who started it!

It was also interesting to read Dr Lauren Stewart's current working hypothesis that earworms are a homeostatic mechanism which help to stabilise consciousness and stimulate the brain to stay vigilant when in danger. I often find myself humming when I am in a situation that puts me under significant stress – a personal observation that appears to back Stewart's theory.

Homeostatic survival mechanisms or not, the next time my colleague accuses me of giving her a Jurassic earworm, I shall correct her and tell her it is merely involuntary musical imagery.

Ellen Morrison, Devon

Population explosion?

In January's issue, I was stunned by the 'Good month/bad month' suggestion that being tall meant a shorter lifespan. I did National Service at 21, and my height was stated as 6ft 3/4in. Later in life I had an accident while cycling to work. It resulted in a crushed vertebra, costing me one-and-a-quarter inches in height. But one loses more height through 'wear' as one's spine ages. However, it has not stopped me from reaching 80 years of age. My mother was above average height and lived to 101. Most of her siblings are still alive – her brothers were all over 6ft, while her sisters were the same height as her. My father and his brother were average height. Dad died at 78, and his brother died a few years later. Everyone expects me and my younger brother to last for a few years yet!

Derek A Knight, Buckinghamshire

Clones no more

The answer to the Stormtroopers question (Christmas, p65) was



Beneath the white body armour lurk individuals, not clones, writes 12-year-old Kalyan

incorrect: Stormtroopers are not clones. The Clone Army (also known as the Grand Army) was abolished at the end of the Clone Wars due to the fact that they aged twice as fast. The Stormtroopers then became a recruitment-based army, therefore making them more unreliable than the clones.

Kalyan Bhattacharya (aged 12), via email

Poetry corner

This poem was written by Charlie Noakes, my six-year-old grandson who lives in London, following his research on Thomas Edison.

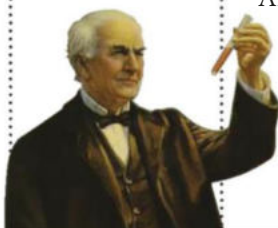
Light bulbs

Light bulbs, light bulbs.
Lots of light bulbs, here and there.
Thomas Edison invented them everywhere.
He was married twice.
They were very nice.
He invented the motion picture and phonograph one day,
The talking doll for kids to play
At home he learned to read and write
And let in the light.

Light bulbs, light bulbs, here and there.

Thomas Edison invented them everywhere.

Tom Holloway, Louisville, Kentucky



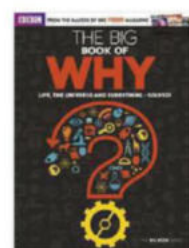
Just like our art editor Joe, Ellen Morrison is also plagued by the theme of a certain dinosaur film

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Model shown is the Jeep Grand Cherokee 3.0 litre V6 Summit at £51,995 OTR including special paint at £720. OFFICIAL FUEL CONSUMPTION FIGURES FOR THE JEEP GRAND CHEROKEE RANGE IN MPG (L/100KM): EXTRA URBAN 29.4 (9.6) – 43.5 (6.5), URBAN 13.9 (20.3) – 30.4 (9.3), COMBINED 20.9 (13.5) – 37.7 (7.5), CO₂ EMISSIONS: 315 TO 198 G/KM. Fuel consumption and CO₂ figures are obtained for comparative purposes in accordance with EC directives/regulations and may not be representative of real-life driving conditions. *Claim relates to Jeep Grand Cherokee nameplate over its lifetime. †Promotion available on Jeep Grand Cherokee 3.0 litre V6 Summit registered by 31st March 2016. Jeep Deposit Contribution only available in conjunction with Jeep Hire Purchase. 0% APR Representative Hire Purchase available for a 3-year term with a minimum deposit of 12% required. Complimentary scheduled servicing for up to 3 years or 30,000 miles whichever occurs first (for SRT up to 2 years or 30,000 miles) on all qualifying retail sales. Finance subject to status. Guarantees may be required. Terms and Conditions apply. Jeep Financial Services, PO Box 4465, Slough, SL1 0RW. Jeep® is a registered trademark of FCA US LLC.

DISCOVERIES

DISPATCHES FROM THE CUTTING EDGE

FEBRUARY 2016

EDITED BY JASON GOODYER

PHYSICS

In quantum physics, two particles can become entangled across vast distances, and even across time

SHARING MEMORIES, THE QUANTUM WAY

Physicists reveal bold plans to teleport the 'memory' of bacteria

We may still be a long way from *Star Trek*-style Vulcan mind melds, but we could soon be teleporting memories from one living thing to another. An international team from Purdue University, USA and Tsinghua University, China has published a paper detailing a potential method of teleporting quantum information, or 'memories', between two bacteria.

The technique relies on a phenomenon known as quantum superposition, in which particles exist in all possible states simultaneously until they are observed and fall into one known state. The most famous example of this was described in Erwin

ALBERT EINSTEIN FAMOUSLY DUBBED QUANTUM ENTANGLEMENT “SPOOKY ACTION AT A DISTANCE”

stays alive. But until the box is opened and we learn the fate of the cat, it is in a superposition of both alive and dead states.

The experiment is also an example of another quantum mechanical phenomenon called entanglement. Famously dubbed “spooky action at a distance” by Albert Einstein, entanglement occurs when particles are connected in such a way that their interactions can be predicted regardless of how far apart they are. In the Schrödinger’s cat experiment, the state of the cat is said to be entangled with the state of the radioactive material. If we open the box and the cat is dead, we know the material has decayed.

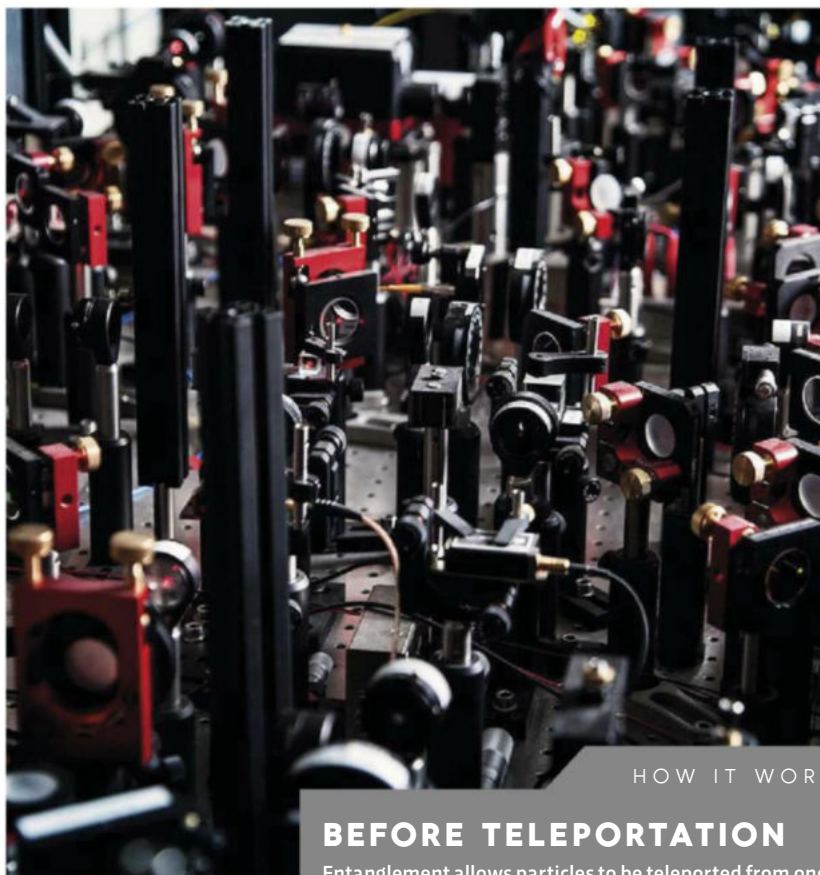
In 2013, researchers at the University of Colorado successfully put an aluminium membrane into a superposition of states by rapidly vibrating it. By cooling a bacterium down to just above absolute zero to cut down its chemical activity and placing it on top of such a membrane, the team at Purdue believe they can put it into a superposition state, effectively meaning it will be in two places at once.

Next, they plan to take advantage of entanglement to join together information about the bacterium’s internal state and motion and quantum teleport it to a second bacterium.

“We propose a straightforward method to put a microorganism in two places at the same time, and provide a scheme to teleport the quantum state of a microorganism,” said researcher Tongcang Li. “I hope our unconventional work will inspire more people to think seriously about quantum teleportation of a microorganism and its potential applications in future.”

Quantum teleportation has already been demonstrated with photons, atoms and superconducting circuits but so far, never with a living organism.

➔ Schrödinger’s famous thought experiment in which a cat is locked inside a box rigged with a poison delivery system triggered by a chunk of radioactive material. If the material decays, the poison is released and the cat dies; if the material doesn’t decay, the poison stays put and the cat



PHOTOS: TU DELFT, ROY KALTSCHMIDT/BERKELEY LAB

ABOVE: In a prior experiment, photons were guided from one diamond to another using optical equipment

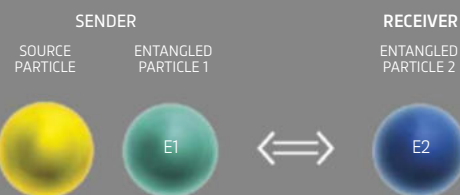
BELOW: Tongcang Li of Purdue University in Indiana, who was involved in the research



HOW IT WORKS

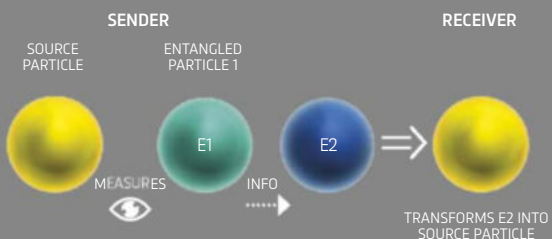
BEFORE TELEPORTATION

Entanglement allows particles to be teleported from one place to another. The ‘source’ particle to be transported is allowed to interact with one of a pair of entangled particles, whose partner (the ‘receiver’) is then dispatched, physically, to the destination.

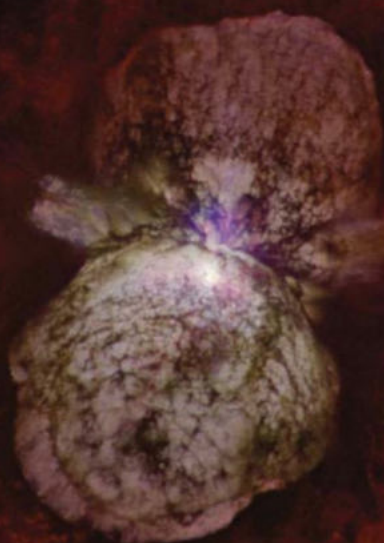


TELEPORTATION BEGINS

The ‘source’ then has all its properties beamed to the receiver by two routes: some directly, and some via the receiver’s entangled partner. This circumvents the uncertainty principle, which forbids perfect knowledge of all a particle’s properties simultaneously. The receiver particle now has the same properties as the source.



This huge nebula formed when a star exploded



SPACE

Huge stars spotted

NASA's Spitzer and the Hubble Space Telescope have spotted five new stars, and they are some of the biggest ever observed.

Two of the new stars have been dubbed 'twins of Eta Carinae' and were found 15 million light-years away in the galaxy M83. The others were found in NGC 6946, M101, and M51, all between 18 million and 26 million light-years away.

Eta Carinae is the most massive and luminous stellar system found within 10,000 light-years of Earth. It is well-known for its eruption in the 1840s, which resulted in the formation of the Homunculus Nebula in which the star system now sits (pictured above).

"The most massive stars are always rare, but they have tremendous impact on the chemical and physical evolution of their host galaxy," said lead scientist Rubab Khan. In fact, these stars generate a lot of elements vital to life before exploding into supernovas.

The researchers plan to further study the stars using instruments on NASA's James Webb Space Telescope (JWST) when it launches in 2018.

IN NUMBERS

60,000
yottayears

The lifetime of an electron, calculated by a team at Italy's Borexino neutrino detector

150
milliseconds

The time taken to recall a memory, as measured by a team at Birmingham University

234,291
km²

The size of a marine wildlife reserve being created by the UK government near Ascension Island in the Atlantic Ocean

BIOLOGY

INSECT SPECS

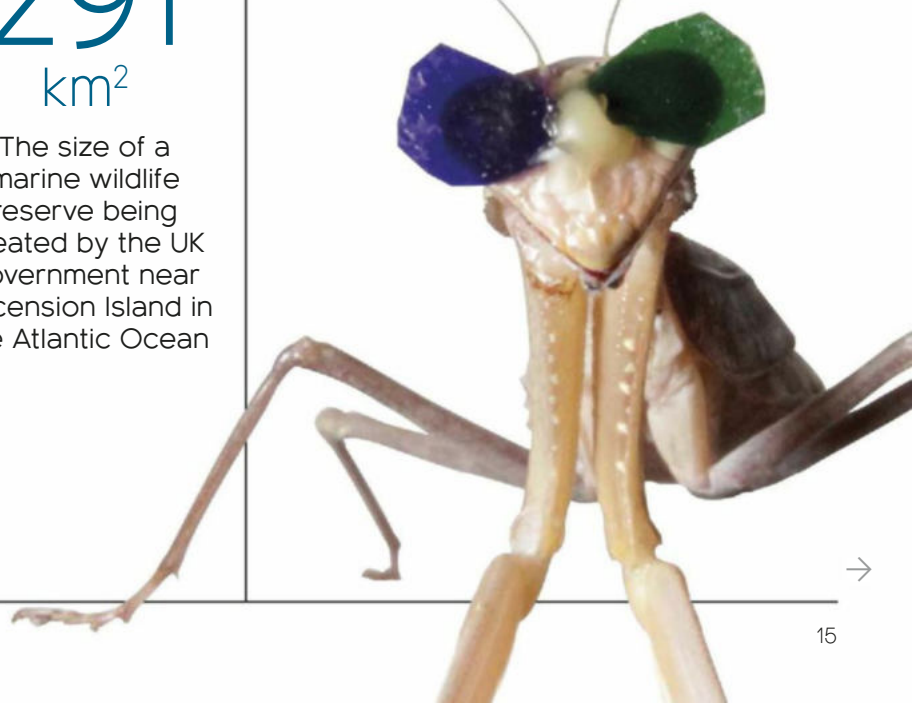
Call it IMAX for insects: a Newcastle University team has created a 3D cinema system to investigate the vision of praying mantises.

The researchers used beeswax to attach specially designed 3D glasses to the insects' eyes, then played them movies of bugs moving around on a screen. When the images were in 2D, the mantises did nothing. When shown the images in 3D, they struck out at them, proving that the insects see in 3D.

The specs used the same principle as the retro blue and red glasses used in old-school 3D cinemas, but with a green lens in place of the red because of the mantises' different colour perception. The more modern system of using polarisation to separate the two eyes' images didn't work because the insects were too close to the screen.

"Despite their minute brains, mantises are sophisticated visual hunters that can capture prey with terrifying efficiency," said study lead Jenny Read. "Better understanding of their simpler processing systems helps us understand how 3D vision evolved, and could lead to possible new algorithms for 3D depth perception in computers."

Until recently, most knowledge about 3D vision has come from vertebrates. These new findings could open up new avenues of vision research.



THE DOWNLOAD

Ununtrium,
ununpentium,
ununseptium
and
ununoctium

What are they?**A robot barbershop quartet?**

Way off. They're four new elements recently added to the periodic table. Their atomic numbers are 113, 115, 117 and 118.

Who found them?

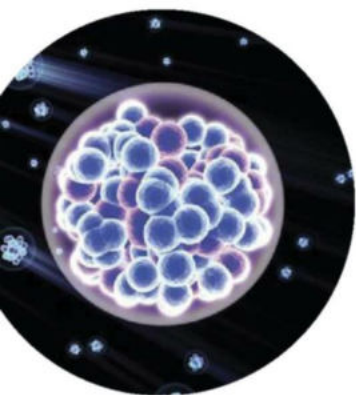
Russia's Joint Institute for Nuclear Research and Lawrence Livermore National Laboratory in California detected 115, 117 and 118. Element 113 was found by a team from Japan's Riken Institute.

How were they created?

By slamming lighter nuclei into one another at high speed and looking for the radioactive signatures produced as the new elements decayed.

But why the silly names?

The current names are just based on the atomic numbers. They'll receive official names in the coming months. Maybe they'll name one Focusium...



MATERIALS

SHAPE-SHIFTING ORIGAMI MATERIAL

As anyone who has tried to fold a square of paper into anything more complicated than an aeroplane will know, origami can be a fiddly and frustrating business.

Now, researchers from the State Key Laboratory of Chemical Engineering in Hangzhou, China, have created a heat-reactive material that does all the work for you.

The polymer is capable of folding itself into precise geometric shapes that are predetermined by the scientists. The material could find its way into everything from medical implants to shape-shifting electronic devices, they say.

The clever material was made by combining crosslinked polycaprolactone (PCL), an elastic material, with triazabicyclodecene (TBD), a plastic material. This allowed the elastic and plastic properties of the

two different materials to be activated by changing the temperature.

At 70°C, PCL's elastic threshold, the material flips between its resting state and a default shape. However, the default shape can be altered by heating the material to 130°C, the plastic threshold. At this point the TBD kicks in by creating chemical bonds between the PCL molecules. The material can then be manipulated into a new default shape.

The final product was able to snap between different shapes – including a boat, a bird and a pinwheel – hundreds of times with little sign of wear and tear.

The team now plans to develop a version of the material that works at lower temperatures. "The biggest challenge for us is not necessarily technical, but rather our imagination of what the possibilities are with this type of shape-shifting behaviour," said Prof Tao Xie (pictured), a materials scientist on the research team.

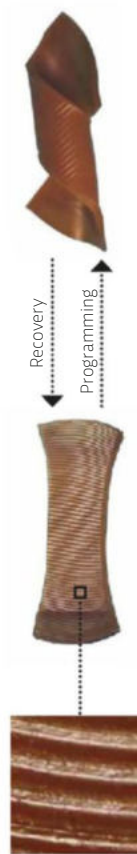


PHOTO: ISTOCK

"THE POLYMER IS CAPABLE OF FOLDING ITSELF INTO PRECISE SHAPES AND COULD FIND ITS WAY INTO SHAPE-SHIFTING ELECTRONIC DEVICES"

ZOOLOGY

Chameleons' impressive tongue-lashing skills recorded

There are no flies on this guy. The thumb-sized *Rhampholeon spinosus* chameleon can flick out its tongue with an acceleration 180 times quicker than a Formula One car. Eat that, Lewis Hamilton!

That's the highest acceleration and power output produced per kilogram of muscle by any reptile, bird or mammal on the planet. Only the salamander – an amphibian – can outdo it. The tongue moves so quickly that researchers used a camera that shoots film at 3,000 frames a second to capture the reptile's skills.

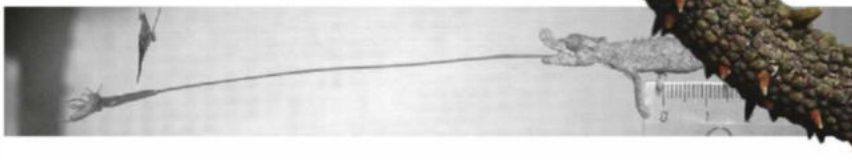
The secret of this chameleon's talent is that it doesn't rely on generating spontaneous muscle power. It stores most of the movement's total energy in elastic tissues in its tongue and then releases it to produce a catapult-like effect.

Chameleons are famous for shooting their tongues out to catch insects, but the full extent of their abilities was unknown as previous research had overlooked the little guys. "What this study shows is that smaller species have higher performance than larger species," explains researcher Dr Christopher Anderson.

All chameleons have the same elastic mechanism but, proportional to their size, smaller ones have more power than larger chameleons. They are like little sports cars with powerful engines, says Anderson.



The implausibly long – and phenomenally speedy – tongue of the *Rhampholeon spinosus* chameleon



THEY DID WHAT?!

Socks and urine used to generate power

What did they do?

Researchers at the Bristol BioEnergy Centre embedded a pair of socks with microbial fuel cells – packs of bacteria that

convert waste fluids into electricity. They added tubing that looped under the wearer's heel and into the fuel cells, before filling the pipes with fresh urine.

What did they find?

Walking in these socks puts regular pressure on the soft tubing, pumping the urine through the microbial fuel cells via a simple circulation



system. The bacteria inside can generate enough electricity to send wireless signals to a PC receiver. No batteries required.

Why did they do that?

Glamorous they may not be, but these socks could save lives, enabling a lost hiker in the wilderness to transmit their coordinates to search-and-rescue teams.

Everyone laughed when Frank said his urine-powered socks would be handy one day...

BEHIND THE HEADLINES

"They've spent vast amounts of money, yet it's only been tested against a really basic computer"

QUANTUM COMPUTING

Google announced that its D-Wave 2X quantum computer solved a maths problem 100 million times faster than a conventional computer. Is the era of quantum computing finally here?

What is quantum computing?

Remember Schrödinger's cat? The decay of a radioactive particle is connected to the death of this cat, and you don't know whether it is alive or dead until you look at it. In a normal computer, the memory is in bits – either ones or zeroes – but, in quantum computers, the 'qubits' could be one or zero or a quantum superposition of those two states. This means that when a quantum computer is trying to calculate the answer, it's as though it's

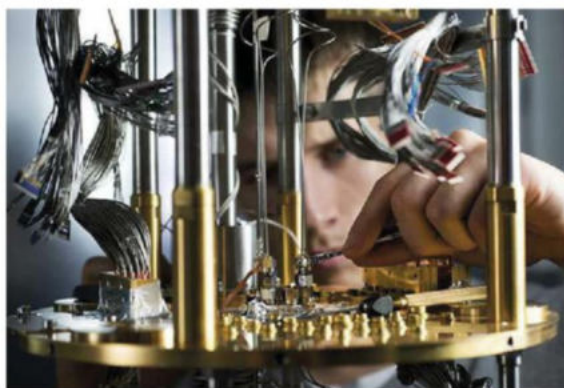
thinking about all the possible answers at the same time – as opposed to a conventional computer having to search through them all.

How does D-Wave 2X work?

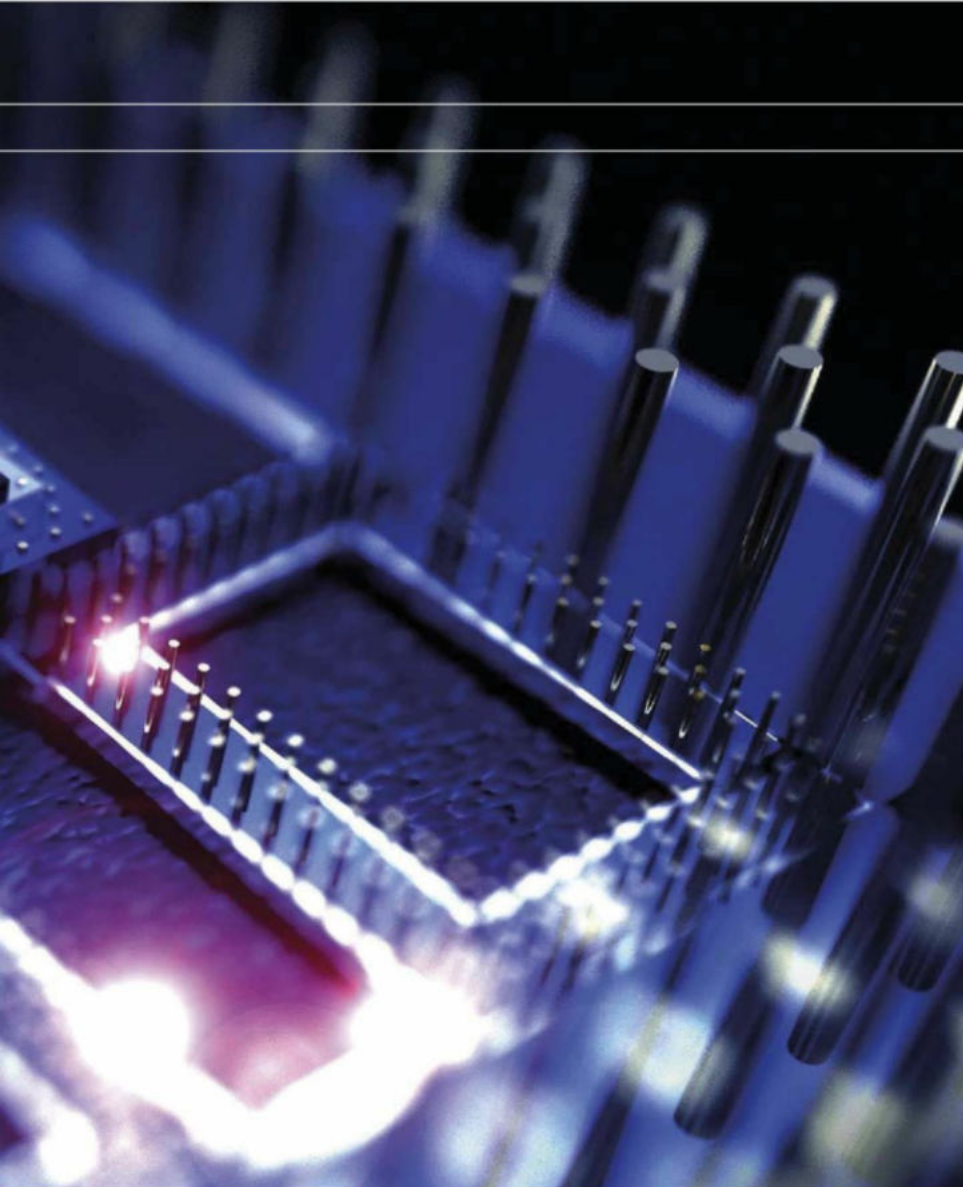
D-Wave isn't really a full quantum computer because it takes a kind of messy approach and doesn't bother with much error correction. It cools things down and lets the qubits fall into their lowest energy state, using the randomness as part of the way of solving the problem. It is cooled down to temperatures colder than the Universe around us, which is why it's hugely expensive.

How do you rate these latest results?

They've spent vast amounts of money, yet it's only been tested against a really basic computer with a single core. In research, we mostly use the graphics processing units of graphics cards, and they can have thousands of cores. Already, that allows conventional processors to do highly parallel computation. If you were to compare it to a normal GPU-style computer, it probably wouldn't be faster.



RIGHT: The D-Wave's power demand will not soar over time, even as its qubits increase



Where does quantum computing go from here?

This [D-Wave] has only about 1,000 bits, which is 125 bytes. Your computer probably has 16GB – millions of times more. It's like looking at digital computers in 1945, before we invented transistors, because we haven't got the hardware quite right yet for quantum computers. From 1945 to now is a long time. It's going to take at least as long as that before quantum computers are usable.

Peter Bentley is not convinced that the D-Wave will launch the field of quantum computing



ILLUSTRATION: GIACOMO BAGNARA

What will quantum computers actually be used for?

If we ever get the hang of them, I'm sure they'll be revolutionary and transformative... but we haven't yet. The area having most success using quantum effects is actually in conventional electronics. We've now shrunk chips to such tiny scales that we're getting quantum effects. Intel may switch from conventional transistors to quantum well transistors, for example. Another example is technology that uses quantum effects to give us great screens. We are using quantum technology in various ways already, and rather more successfully than in quantum computers.



EXAMOPHOBES

If the thought of taking exams leaves you quivering in fear, read on. A team at Stanford University has developed an algorithm that, with 85 per cent accuracy, can predict whether or not students will answer a question correctly.

WORRIERS

Don't panic! French researchers have found that anxious people have a 'sixth sense' that could help them avoid danger. The effect is due to worriers being more likely to process potential threats in the regions of the brain associated with action.

GOOD MONTH

BAD MONTH

DISTRACTED PARENTS

Want your baby to grow up happy? Then ditch your smartphone. Researchers at the University of California, Irvine have found that rat pups raised by caring but chaotic mothers grew up with little interest in sweet food and play – key measures of their ability to enjoy life.

MIDNIGHT FEASTERS

While the odd late-night biscuit binge won't do you much harm, making it a habit may damage your memory. According to a University of California study, mice fed during sleep time performed worse in learning and memory tasks.



BIOLOGY

DINOSAUR VEINS FOUND IN 80-MILLION-YEAR-OLD FOSSIL FROM MONTANA

The blood vessels found in the leg bone of a hadrosaur may help to shed light on the evolutionary relationships between species

The delicate, spindly strands pictured below are blood vessels belonging to a hadrosaur that roamed the Earth 80 million years ago.

The vessels were extracted from the leg bone of a *Brachyophosaurus canadensis*, a 9m-long duck-billed dinosaur that lived in what is now Montana, USA, by researchers from North Carolina State University. They then analysed the tissue using a high-resolution mass spectrometer and discovered several of the proteins that make up the cells of blood vessels.

"This study is the first direct analysis of blood vessels from an extinct organism and provides us with an opportunity to understand what kinds of proteins and tissues can persist and how they change during fossilisation," said researcher Tim Cleland.

The researchers subsequently confirmed their results by performing the exact

same process with bones from modern archosaurs, such as chickens and ostriches, which are relatives of the dinosaurs.

"THIS IS THE FIRST DIRECT ANALYSIS OF THE BLOOD VESSELS OF AN EXTINCT ORGANISM"

In both the modern and ancient samples, the sequences of amino acids – the building blocks of proteins – matched those found in blood vessels.

"This will provide new avenues for pursuing questions regarding the evolutionary relationships of extinct organisms," said Cleland.



WHAT WE LEARNED THIS MONTH

RIISING SEA LEVELS ARE SLOWING DOWN EARTH'S ROTATION

So suggests a study conducted by Harvard University. The effect is due to a shift in mass from the poles to the equator as ice melts, but it poses no threat to the planet, the researchers reassure.

AMERICANS' TEETH ARE NOT IN BETTER CONDITION THAN THOSE OF BRITS

A study of 9,000 Brits and 10,000 Americans carried out at University College London has found that there's actually little difference in the state of their gnashers, contradicting the belief of superior US dentistry.

A FULL SOCIAL LIFE COULD BE JUST AS IMPORTANT AS DIET AND EXERCISE

Researchers from the University of North Carolina have found a link between social relationships and measures of well-being, such as high blood pressure and obesity.

ALLERGIES COULD COME FROM NEANDERTHALS

A study by Germany's Max Planck Institute has found that three genes thought to originate from Neanderthals cause the immune system to overreact to stimuli such as dust and pollen.



PHOTO: CORNELL UNIVERSITY

GENETICS

Say hello to the world's first test tube puppies

Though they may appear no different from any other puppies, these adorable bundles of fur are two of the first pooches to be born via in vitro fertilisation (IVF).

IVF, a technique in which eggs are fertilised with sperm outside the body and then implanted into the womb, has been used in humans since the 1970s. However, researchers have struggled to carry out the technique in dogs thanks to differences in their reproductive cycles.

If used alongside genome editing techniques, researchers may one day be able to remove genetic diseases and traits from an embryo, ridding dogs of heritable diseases, including those resulting from the selective breeding of pedigree animals.

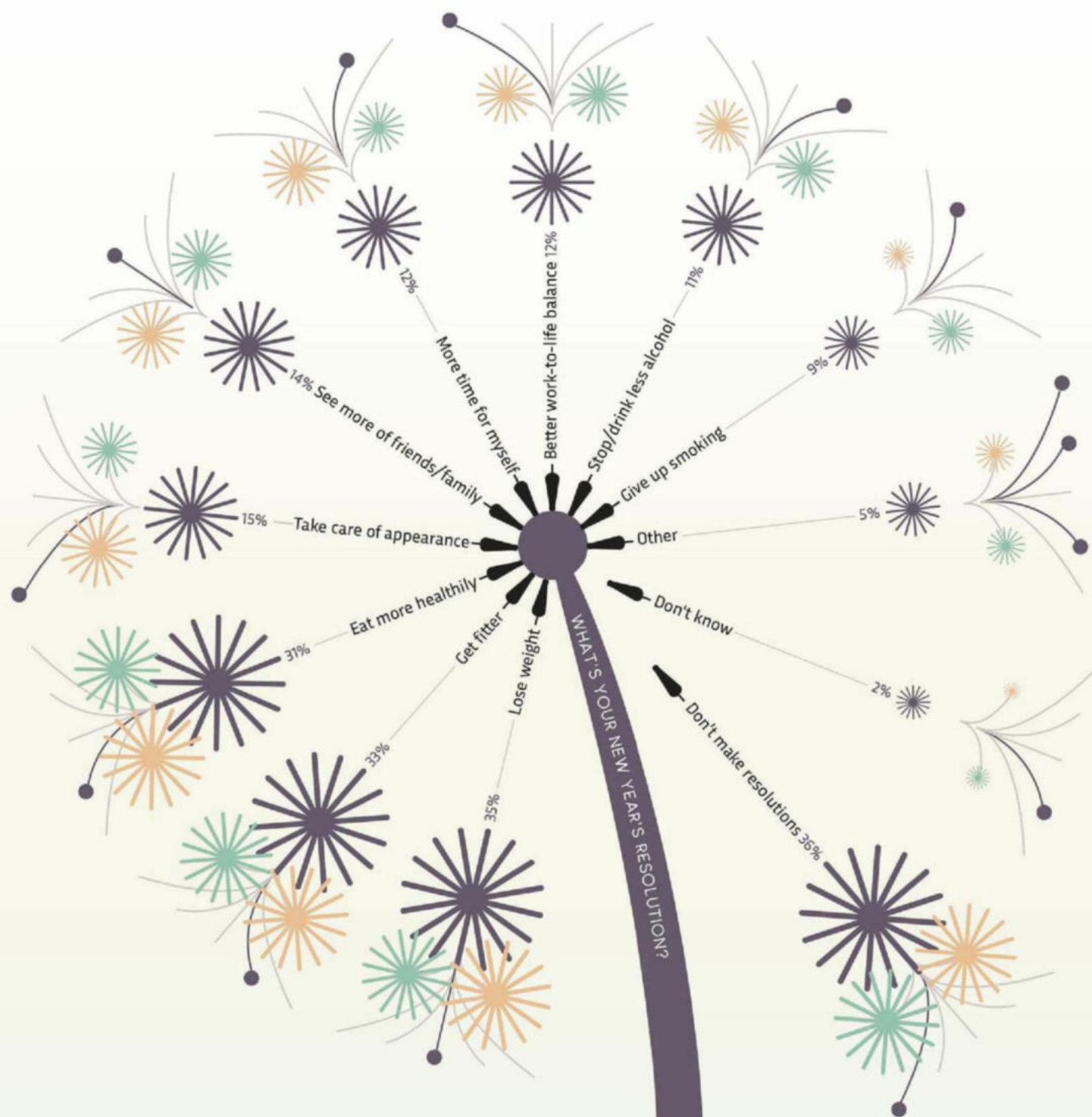
A total of seven puppies – five beagles and two beagle/spaniel crosses – were successfully delivered from their host mother by researchers at Cornell University last summer, but were kept under wraps until the publication of the study in the journal *PLOS ONE*.

“With a combination of gene editing techniques and IVF, we can potentially prevent genetic disease before it starts,” researcher Alex Travis said.

Moreover, as dogs share more than 350 similar heritable disorders and traits with humans – almost twice the number as any other species – the research could offer a “powerful tool for understanding the genetic basis of diseases,” he added.

The breakthrough also opens the door for conserving endangered species, by allowing conservationists to store semen and eggs and bring their genes back into the gene pool when they are required.

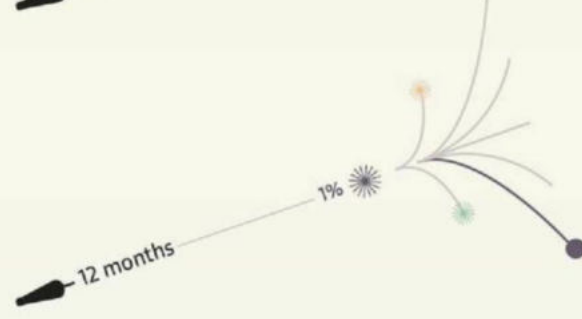
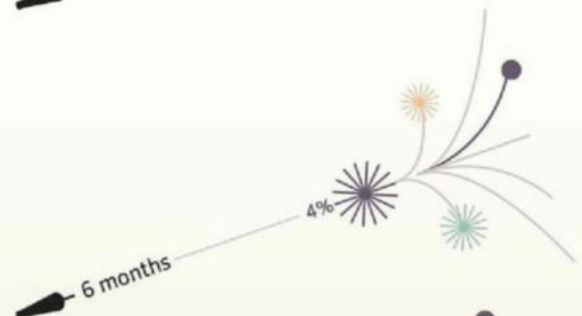
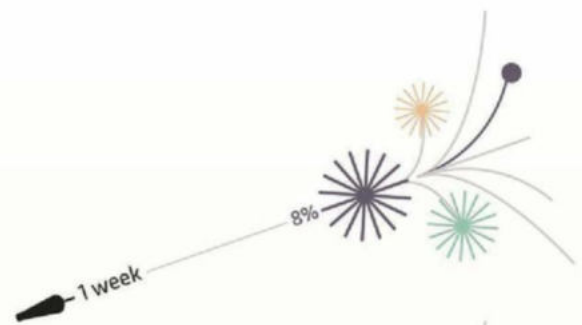
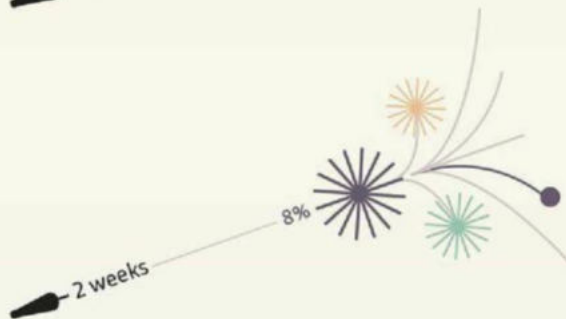
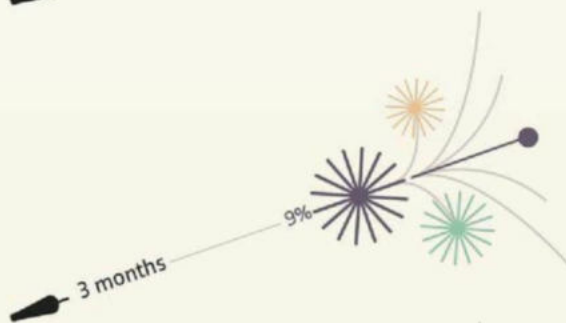
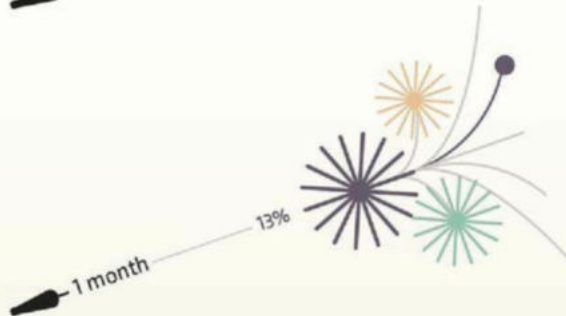
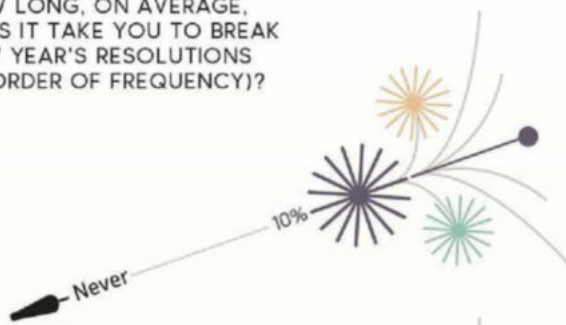




NEW YEAR, NEW YOU?

Many of us start the new year with such great intentions. Whether we want to lose weight, get fit or give up smoking, we convince ourselves that *this year* will definitely be the one where we'll make that big change. But if you've already reverted back to your wicked old ways, you're in good company. According to a study carried out by YouGov last year, 32 per cent of resolutions are broken within a month.

HOW LONG, ON AVERAGE,
DOES IT TAKE YOU TO BREAK
NEW YEAR'S RESOLUTIONS
(IN ORDER OF FREQUENCY)?



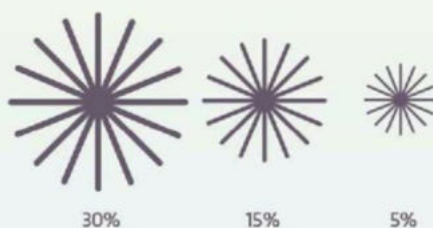
HOW TO READ
THE VISUALISATION

Scale as % of total respondents
Sample size: 2,025 GB adults

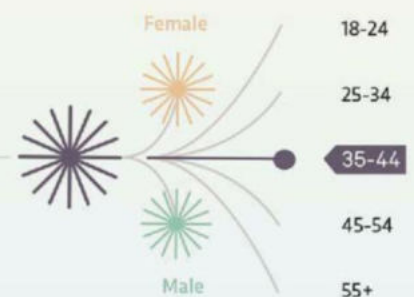
Total
responses

Share of total
by gender

Prevalence
by age



Response



Data Source: YouGov, 2015

the gadget show

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ABSOLUTELY BRILLIANT. CAN'T
WAIT FOR #GSL2016

DANNY ON INSTAGRAM

THIS WAS A FANTASTIC FAMILY
DAY OUT!! WE LOVED THE SHOW!!

DANIELA ON FACEBOOK

I HAD AN EXCELLENT DAY,
COULDN'T OF BEEN BETTER
TO BE HONEST, THE TECH
WAS JUST AMAZING!!

RYAN ON FACEBOOK

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SOUND AND VISION

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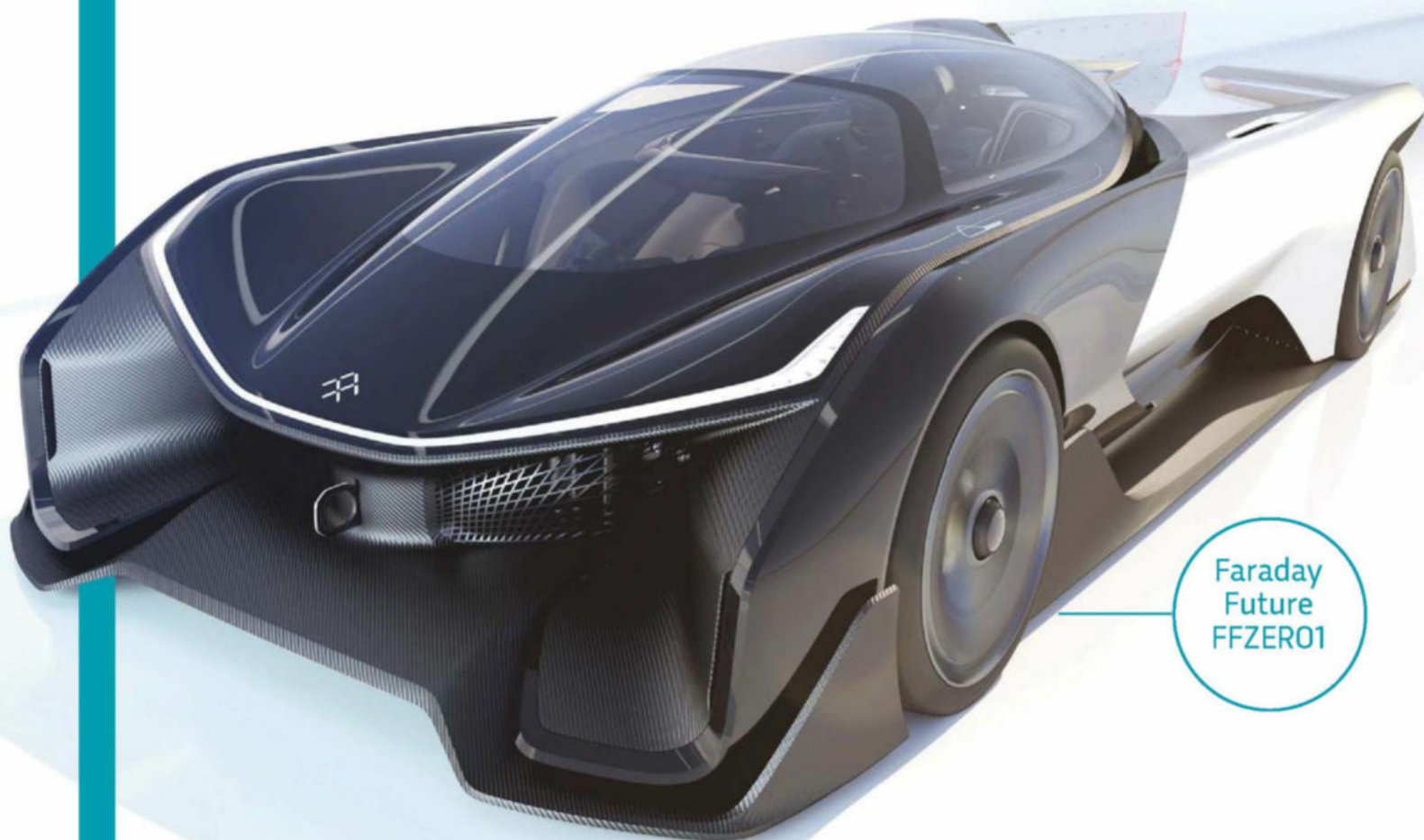
Gadget

INNOVATIONS

PREPARE YOURSELF FOR TOMORROW

FEBRUARY 2016

EDITED BY RUSSELL DEEKS



Faraday
Future
FFZERO1

THE EXTREME MACHINE

*An autonomous electric
concept vehicle with
billions of dollars behind it*

There are a lot of changes in the world of automobile technology right now, and one of the star attractions at this year's CES show was a concept car that wraps them all up in one neat package. The FFZERO1 is the brainchild of Faraday Future, an auto-technology company based in California and established in 2014. Although the FFZERO1 is strictly a concept – and a concept racing car, at that – Faraday Future is building a new \$1bn plant in Nevada, because it plans to bring the tech showcased on the FFZERO1 to market within the next couple of years.

And what a list of technologies that is. For starters, the FFZERO1 is fully electric, ➔



FFZERO1's augmented reality dock can help you navigate

➔ with four 1,000bhp motors that can push it to speeds exceeding 320km/h (200mph) and take you from 0-60 in less than three seconds. It's also autonomous, so you can leave it to drive itself if you want to. And if you do want to, you can keep yourself amused by taking advantage of the car's cutting-edge electronics, which centre around a tablet/smartphone dock in the steering wheel. Thanks to funding from Letv (think: the Chinese YouTube) there'll be access to a range of streamed entertainment, while as well as all the navigation gubbins you'd expect, there's the ability to project augmented reality (AR) items onto the road in front of you. Presumably the latter refers to

"IT'S LIKE THE BATMOBILE CROSSED WITH KITT FROM KNIGHT RIDER"

things like arrows that tell you when to turn right or left, or gradient lines to denote a particularly nasty camber, rather than your daily commute becoming an AR version of *Grand Theft Auto*...

The FFZERO1 also features an aerodynamic carbon-fibre shell, a driving seat based on NASA research into zero-g ergonomics that positions the driver at a 45° angle, and a heads-up display inside the helmet visor (this is a race car, don't forget). It's exactly the kind of beast you might expect if you brought together a team of engineers and designers poached from the likes of Tesla, Lotus, BMW and Porsche – which, of course, is exactly what Faraday Future has done.

It's also precisely the kind of sleek speed machine you might expect to see if you crossed the Batmobile with KITT from *Knight Rider* – which is exciting in itself. Now let's see how many of its design and engineering innovations find their way to the eventual production vehicle...

BEST OF THE REST

The FFZERO1 isn't the only exciting concept around



VOLKSWAGEN BUDD-E

The VW BUDD-e is an all-electric people carrier with a large touch/voice-controlled screen that combines your dashboard and infotainment systems. Other advanced features include swipe-based control of indicators, wipers and so on, and camera/screen setups to replace the wing mirrors.



HOTZ SMART CAR

George Hotz, aka hacker Geohot, has kitted out an Acura ILX saloon with a Linux-based AI system that learns your driving habits, and Lidar to detect other vehicles and pedestrians. Together, they form a DIY autonomous vehicle kit that Hotz hopes to sell for under \$1,000.



RINSPEED ΣTOS

This self-driving concept car from Swiss automotive think tank Rinspeed is based on a BMW i8. Innovations include a retractable steering wheel (for greater comfort when in autonomous mode), eight HD cameras that give you 360° vision, and a DJI drone and landing pad so you can check traffic conditions ahead.

WEARABLES

First patch-like wearables arrive



Tech tattoos to track your health – no needles required!

The next generation of paper-thin wearable sensors are on the way. At CES, medical research firm MC10 showed off two products, both resembling a plaster. My UV Patch monitors exposure to harmful rays and feeds that info to a smartphone app. BioStamp Research Connect, meanwhile, is aimed at researchers investigating neurodegenerative and motor disorders.

Elsewhere, Austin-based start-up Chaotic Moon has developed temporary 'circuit board tattoos' made of conductive ink that, similarly, can monitor your blood pressure, temperature and heart rate, and then simply be peeled off when you're finished. Chaotic Moon suggests that in the future, GPS tracking or Apple Pay-like capabilities could be added to the electronic tattoos.



DRONES

Meet the world's first passenger drone

This might make the morning commute a bit more exciting: Chinese technology company Ehang, Inc has just launched the world's first drone capable of carrying a passenger.

Dubbed the Ehang 184, the electric-powered quadcopter was unveiled at CES. It's capable of carrying a load of up to 100kg, which is about the same as an average-sized man and a bag of luggage. It can remain airborne for 23 minutes and takes just two hours to fast charge. Its average speed isn't too shabby either, clocking in at around 100km/h.

Once the flight path has been programmed into the drone using a tablet, passengers need only tell it when to take off and land. Eat your heart out, George Jetson.

PHOTOS: NEWSPRESS, GETTY

Total immersion in virtual reality



VIRTUAL REALITY

Shakin' all over

Nope, this isn't the latest *X-Men* costume – it's the Teslasuit, a full-body haptic feedback device for use with virtual reality systems.

This neoprene two-piece uses dozens of electrodes to deliver low-power shocks to key muscles. These electrical impulses trick the brain into thinking you've walked through a wind tunnel, been hugged by the person you're talking to on Skype or been shot in the back by your in-game enemies, for example. Exact applications are still TBC, given that the suit is still only at the prototype stage.

With dozens of VR headsets – like the Oculus Rift – due to go on sale this year, there's bound to be a whole suite of technologies, like this, designed to create ever more immersive experiences. For example, The University of Bristol is working on a system that uses jets of air to mimic the sensation of touch. The Teslasuit is currently on Kickstarter so it may not happen, or look like this. But it seems inevitable that the rise of VR (see p68), will spawn something similar soon.



WANTED!

YOU RANG?

NINEBOT SEGWAY

The 21st Century may have failed, thus far, to bring us all jetpacks, but robot butlers are another matter. Developed by a consortium that includes Intel and Segway, NineBot is a Segway-like 'personal transporter' that doubles up as a telepresence robot. It's got built-in cameras and microphones for face and voice recognition, along with detachable arms for carrying stuff. Segway hopes to bring it to market by the end of the year.

ETBC, robot.segway.com



Convert
your record
collection
to digital



BLACK BEAUTY

SONY PS-HX500 TURNTABLE

With the vinyl revival in full swing, sales of turntables are booming – HMV sold one *per minute* over Christmas. Sony's getting in on the act with the PS-HX500, which features an analogue-digital converter and USB output as well as switchable line/phono outs. It's been designed for capturing high-res digital recordings from vinyl in WAV or DSD format, as well as for everyday listening, and comes with its own editing app.

£400, sony.co.uk



A CONSOLE FOR CANINES

CLEVERPET

When dogs are left alone all day, they get bored – and when dogs get bored, they have a habit of gnawing things. Things like new sofas and your best brogues, for instance. But CleverPet thinks it has the answer, in the form of this feeder that dispenses a canine treat when Fido successfully completes one of several Simon-like challenges.

£200, getcleverpet.com

SMARTER CYCLING

VARIA VISION

Heads-up displays (HUDs) are getting everywhere these days, from car windscreens to ski goggles. And now cyclists can get in on the act with Varia Vision, a clip-on HUD that provides speed and distance data and smartphone notifications without you needing to take your eyes off the road. Teamed with Garmin's Varia Radar rear light, it'll even tell you when a car's coming up behind you.

\$400 (£275 approx), garmin.com



TODDLER TRAINER

THINK & LEARN CODE-A-PILLAR

According to some experts, coding skills will soon be as vital to children as English and maths. This colourful new Fisher-Price toy aims to give your kids a head start. Each of the Code-A-Pillar's eight body segments represents a different chunk of code – 'turn left', say, or 'play a song'. How your child strings them together will determine the Code-A-Pillar's behaviour, and so help your little 'un develop problem-solving abilities.

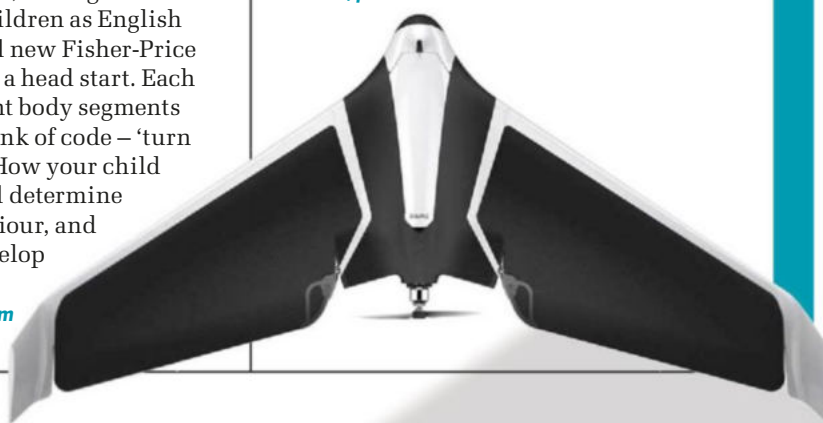
\$50 (£35 approx), fisher-price.com

PLANE SPEAKING

PARROT DISCO

This year's CES was awash with drones, nearly all of the quadcopter variety. Bucking that trend was the Parrot Disco, a fixed-wing drone. While remote-controlled planes aren't new, the Disco features all manner of clever autostabilising gear, meaning that unlike the average RC plane it's simple enough for novices to fly straight out of the box. Described as "impossible to crash", it's got a 14-megapixel, 1080p video camera, complete with 32GB of storage.

ETBC, parrot.com



APP FEED



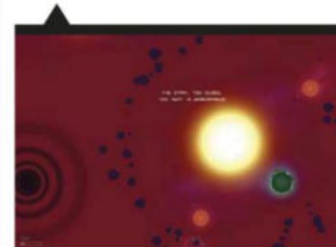
Blippar

Point a device at any object and *Blippar* will identify what it is and supply relevant info. *Free, iOS/Android/Windows*



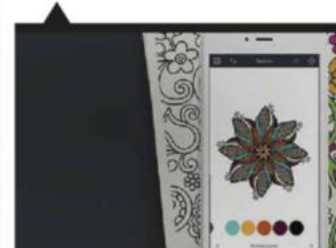
Last Horizon

This minimalist game puts you in the driving seat of a fallen civilisation's last spaceship. File under 'simple but addictive'. **£2.29, iOS/Android**



Recolor

Colouring books are a useful tool for boosting mindfulness. This app gives you 350 designs to colour, with more available as in-app purchases. *Free, iOS*



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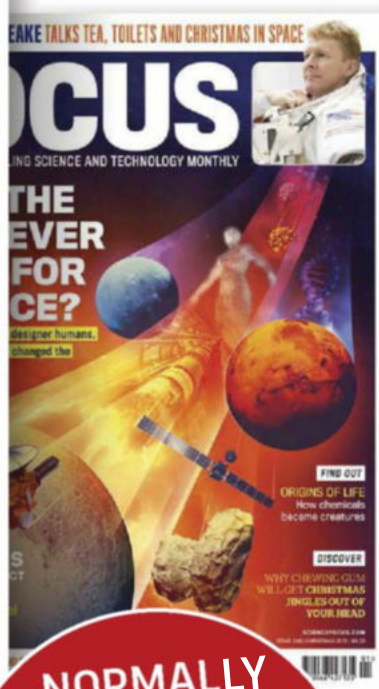
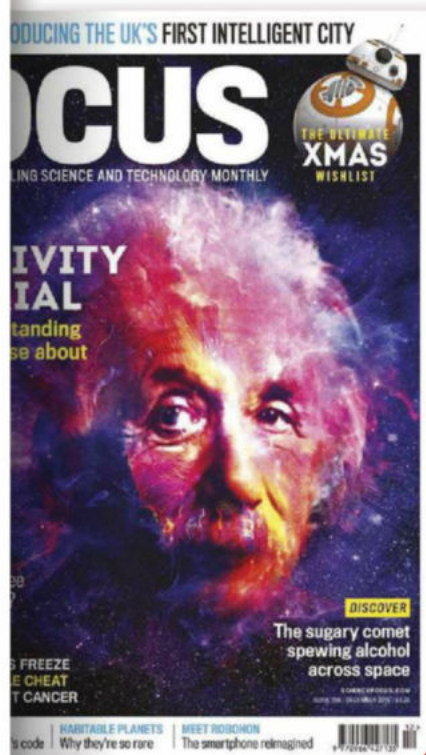
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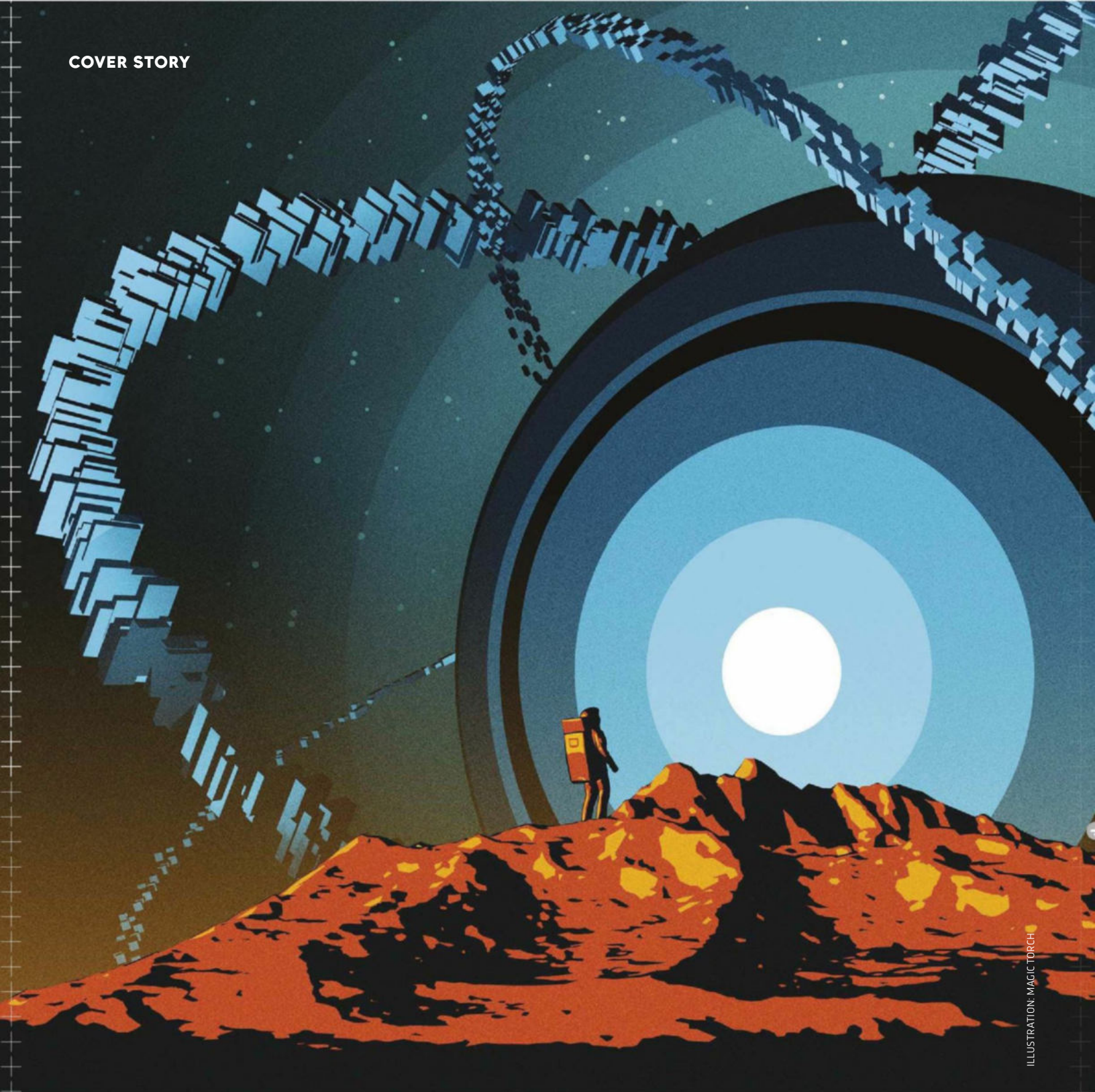
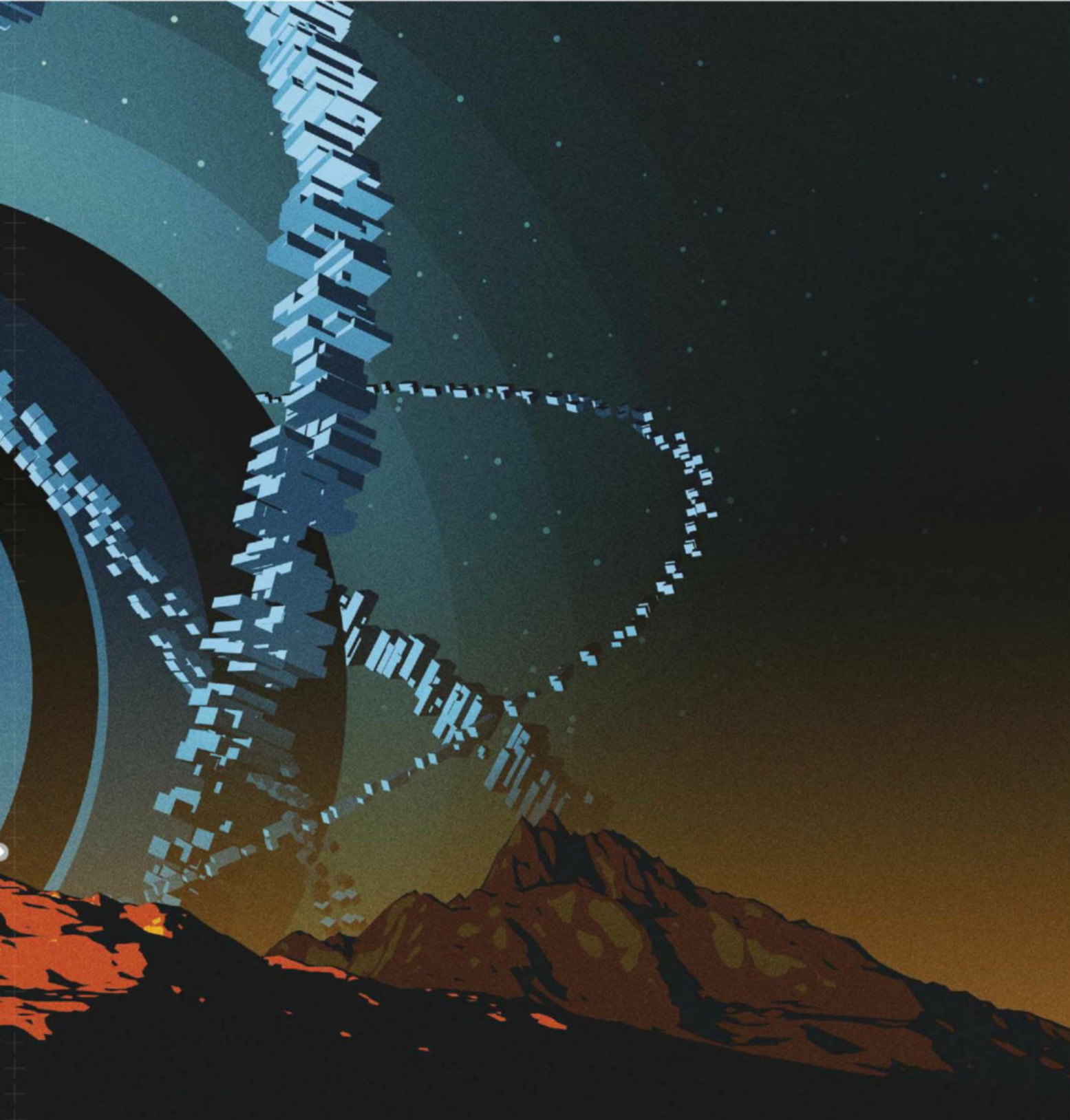


ILLUSTRATION: MAGIC TORCH

WHAT IF WE FIND ALIEN LIFE?



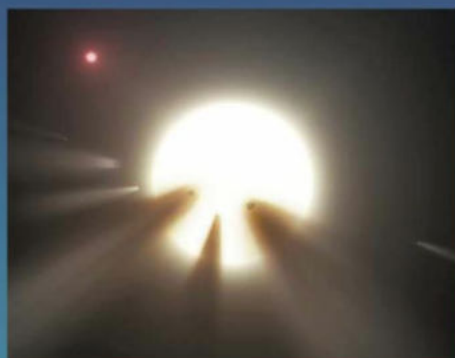
A new, highly funded search for extraterrestrial intelligence is about to launch. We look at what will happen if we actually do end up making first contact

Words: **Colin Stuart**



Over two decades ago, the first alien planet was detected orbiting another sun. We've since spotted more exoplanets, but no discovery has caused a stir quite like the star KIC 8462852. The odd nature of this alien solar system came to light in September 2015 when astronomers were using Kepler to look for dips in the star's brightness caused by any orbiting planets passing across its face.

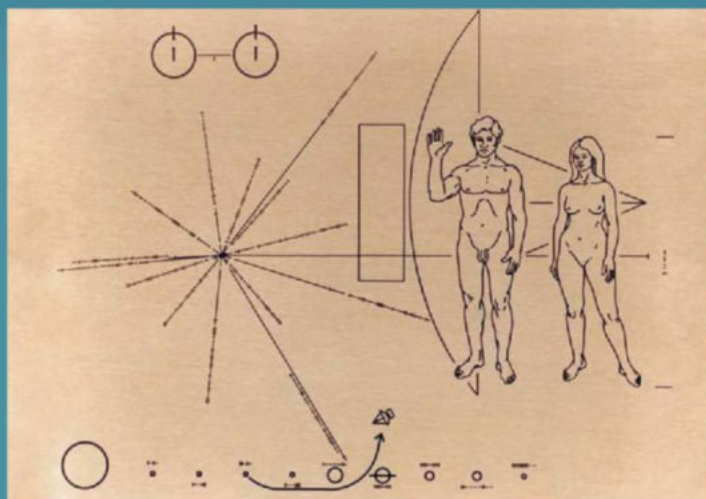




LEFT: Comets could be responsible for KIC 846285's strangely varying brightness

RIGHT: SETI founder and Drake Equation writer Frank Drake at home in 2015. The window depicts the Arecibo message (see p42)

BELOW: Pictorial plaque attached to the outside of the Pioneer 10 and 11 craft in 1972 and 1973



➔ Given that stars are enormous, and planets much smaller by comparison, these fluctuations are usually tiny. Even a Jupiter-sized planet passing in front of a star like the Sun only results in a 1 per cent change. And yet astronomers saw KIC 8462852's brightness plummeting by up to 22 per cent. Nothing like it had ever been seen before.

What rocketed the find into the news was the fact that some commentators suggested aliens might be responsible for the drop. Since it was too big to be caused by a single planet, some theorised huge megastructures created by an intelligent civilisation might be blotting out the star's light. They imagined the dimming could be caused by vast banks of solar panels orbiting the star.

Of course there were other, far less fantastic explanations – some said it was likely that a huge swathe of comets was collectively blocking our view. Louisiana State University's Bradley Schaefer disagrees. After poring over data, he found that the dimming has been going on for more than a century. His calculations show that nearly 650,000 giant comets would have had to pass by the planet during this time to create the recorded patterns, something he's dubbed "completely implausible".

The astronomers behind the Search for Extraterrestrial Intelligence (SETI) project pointed the radio dishes of the Allen Telescope Array at the

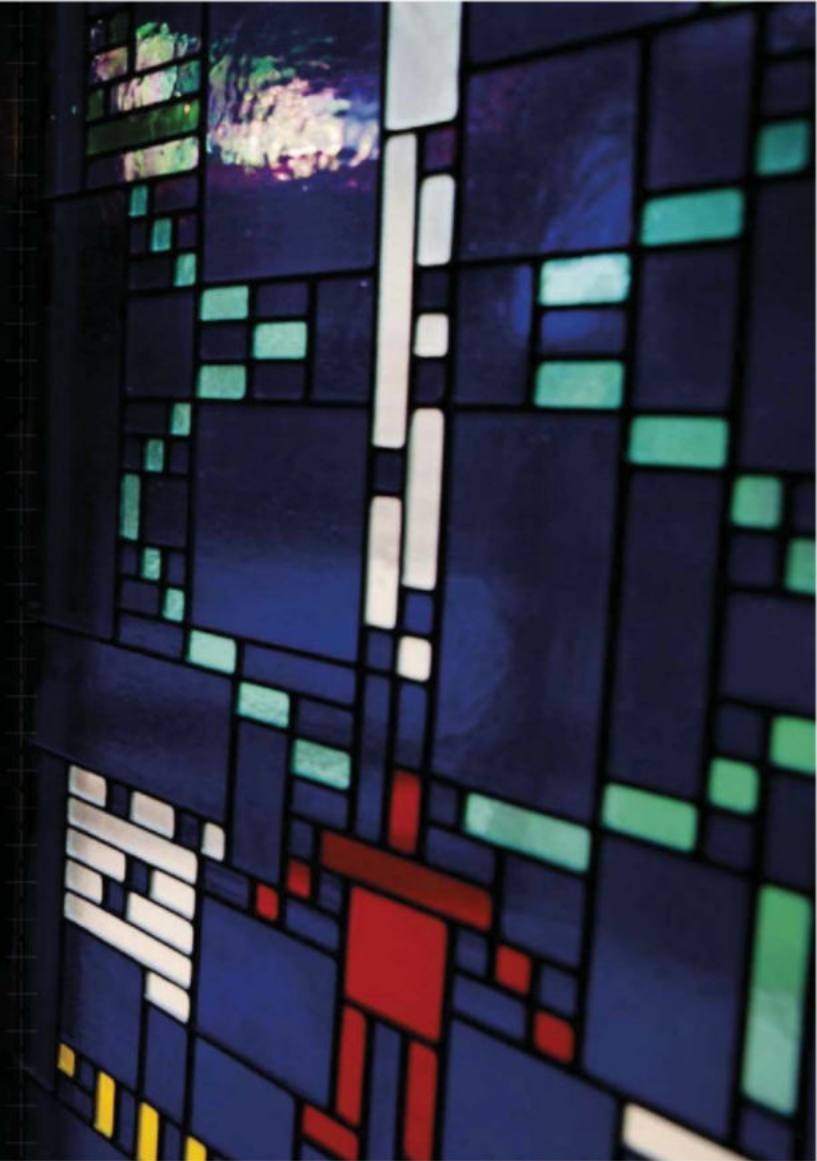
star, just in case they could hear something. "We found no indication of an extraterrestrial civilisation at the other end of the telescope," says SETI's Douglas Vakoch.

If KIC 8462852 turns out to be a dead end, it'll be the latest in a line of blanks. Ever since astronomer Frank Drake undertook the first SETI experiment in 1960, we've detected no signals that we can definitively say are alien in origin. But that may be about to change.

"Astronomers estimate there could be 60 billion potentially habitable planets in our Milky Way"

A BIGGER, BETTER SEARCH

Our quest to learn if we're alone in the Universe is about to kick into overdrive. Last summer Stephen Hawking and Russian entrepreneur Yuri Milner launched Breakthrough Listen, a 10-year, \$100m (£66.5m) project billed as the biggest scientific search ever undertaken for signs of intelligent life, which kicks off this month. Utilising two of the biggest radio telescopes on the planet – the 100m Green Bank Telescope in the US and the 64m Parkes Telescope in



Australia – it'll be more than 50 times as sensitive as previous searches and will cover 10 times more of the sky. It will also listen over a frequency range five times greater than before and will scan through them 100 times as fast. It will eavesdrop on the million closest stars and 100 nearest galaxies for any sniff of civilisation. The search will be sensitive enough to pick up the equivalent of aircraft radar on any of the 1,000 closest stars to Earth.

The fact that Milner is prepared to spend such a vast sum on hunting for aliens shows just how far we've come. We now live in the era of exoplanet astronomy, with around 2,000 confirmed alien worlds beyond the Galaxy. From what we've found so far, astronomers estimate there could be 60 billion potentially habitable planets in our Milky Way. A famous equation formulated by Frank Drake – the Drake Equation – suggests some of them may host to intelligent life. That's a rich seam to mine. "The search doesn't appear as futile as in the past," says the University of Portsmouth's Bob Nichol, a member of the UK SETI Research Network.

As well as searching for radio signals, the project will also look out for laser transmissions. But with all this excitement about detecting future alien signals, what will we do if we find something?

CONFIRMING FIRST CONTACT

Should we pick up an alien signal, the first hurdle to leap is being able to show definitively that it doesn't come from anything else.

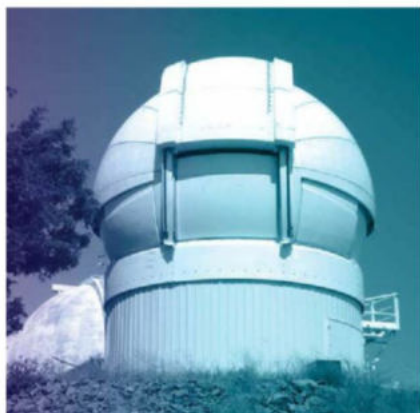


THE TELESCOPES

AUTOMATED PLANET FINDER TELESCOPE

As well as searching for radio signals, the Breakthrough Listen project will also hunt for optical laser signals. This survey will be undertaken by the Automated Planet Finder Telescope (APF) at the Lick Observatory on Mount Hamilton, San Jose, California. As its name suggests, it's fully robotic.

DIAMETER: 2.4m



ROBERT C BYRD GREEN BANK TELESCOPE

Located in West Virginia, USA, this is the world's largest fully steerable radio telescope. It spends 6,500 hours a year listening to space for a variety of astronomical purposes. Perhaps its most notable discovery came when it uncovered one of the heaviest known neutron stars.

DIAMETER: 100m



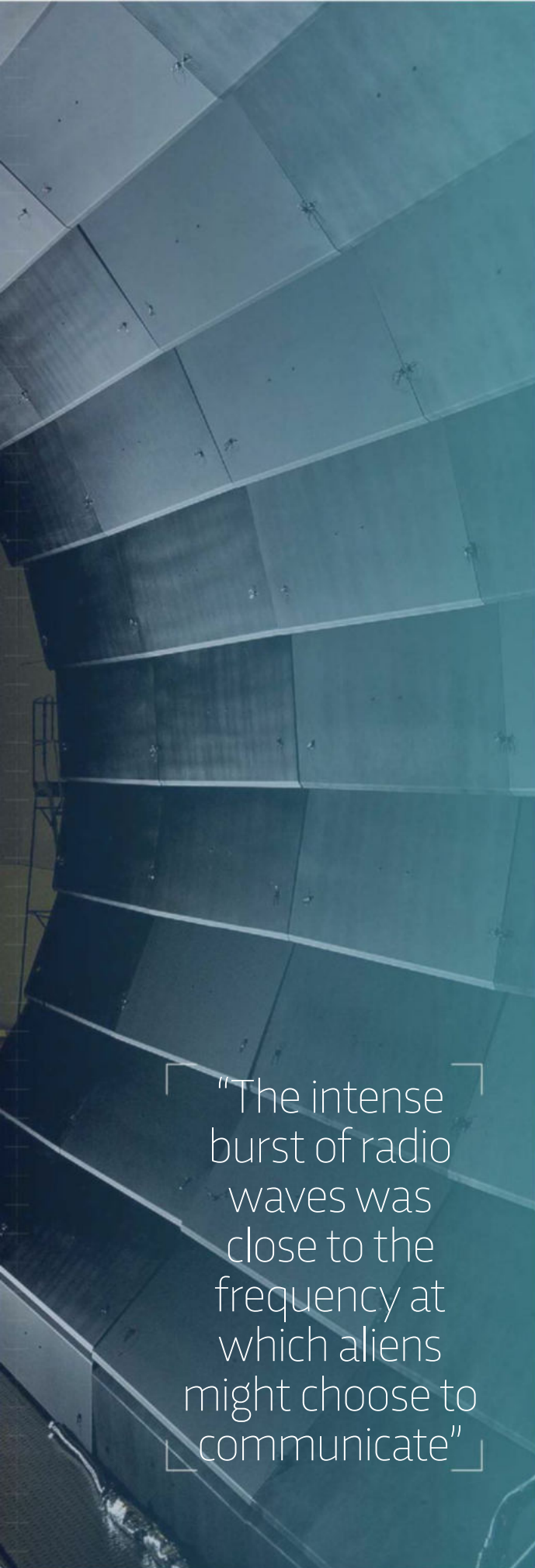
PARKES TELESCOPE

The second-largest cosmic listening station in the Southern Hemisphere, this observatory is named after a nearby town in New South Wales, Australia. It has been scanning the skies since 1961, with highlights including picking up the TV broadcast from the Moon landing in 1969.

DIAMETER: 64m







LEFT: Six segments of the James Webb Space Telescope's primary mirror being tested at NASA's Marshall Space Flight Center. When complete, the telescope will search for the most distant objects in the Universe

BELOW: The Wow! signal was picked up by the Big Ear telescope in Ohio in August 1977, but no similar signal has been detected since

“The intense burst of radio waves was close to the frequency at which aliens might choose to communicate”

➡ “To start with, you’d have to put a low probability on it being alien,” says the University of St Andrews’ Duncan Forgan. Once other possibilities have been ruled out, he believes there are important checks that must be carried out. “The first is whether it’s reproducible,” he says.

If a signal is just a one-off then it’s hard to tell anything about it. This is well illustrated by the Wow! signal heard in August 1977. The intense burst of radio waves lasted for 72 seconds and was very close to the frequency that SETI researchers believe an alien civilisation might choose to communicate at. When astronomer Jerry Ehman first saw the signal on a printout from the Big Ear radio telescope in Ohio, he wrote ‘Wow!’ next to it in red ink. But despite various efforts since, no repeat signal has ever been heard coming from that part of the sky. If a repeat is found, you can confirm it is coming from another planet by the way that planet’s motion affects the signal. “There should be a measurable shift in its spectrum due to the velocity of the planet around the star compared to us,” says Forgan.

If the discoverer(s) of the signal cannot find anything to rule out aliens, they’ll then throw it open to others teams of astronomers who will do their best to prove it isn’t from ET. “Any suspected signal would become the subject of extreme scrutiny,” says Forgan.

If extraterrestrial technology remains the most plausible explanation then, according to the official ETI Signal Detection protocol, that information should be passed to the UN Secretary General as well as a host of other international organisations. The frequency at which the signal was heard will be protected to keep that channel free from any other radio clutter, and no reply is to be sent until ➡

PHOTOS: NASA, GETTY





LORD MARTIN REES

Astronomer Royal

The prestigious British stargazer tells BBC Focus what alien signals will look like

What drew you to Project Breakthrough?

Well, I think SETI (Search for Extraterrestrial Intelligence) is clearly an enterprise where the pay-off from success would be huge. It would be one of the greatest discoveries of all time and would interest a far wider public than other discoveries. But none of us involved would rate the chance of success as more than a few per cent, and I would rate it less than that. Nonetheless, given that there's so much public interest, I think it's hugely welcome that Yuri Milner has offered substantial funding for this activity – otherwise the chance of discovering ET in our lifetime would be zero.

What sets this venture apart from SETIs before it?

It'll be much more sensitive in terms of being able to detect faint signals and in terms of wavelength coverage. So it'll be a more

comprehensive search than has been done hitherto. The initial focus is on radio searches, but we should carry optical searches too, and use all possible techniques as they become available.

Let's say you pick up a signal – what are the next steps?

There have been lots of suggestions. In fact the International Academy of Astronautics set up the SETI Post Detection Task Group [of which *BBC Focus* contributor Stephen Baxter is a member]

for just this job. Their role is to lay out the first steps towards first contact. The group is led by Paul Davies, who is on our committee.

What might an alien signal look like?

We would be looking for a signal that was not natural. It might have a very narrow bandwidth, or be pulsed. But even if it were clearly artificial, that wouldn't mean it was a message that we could decode. My guess is that it wouldn't come from a

“The signals wouldn't come from a civilisation of organic beings but from some hyperintelligent machine”

PHOTO: GETTY



civilisation of organic beings but from some hyperintelligent machine.

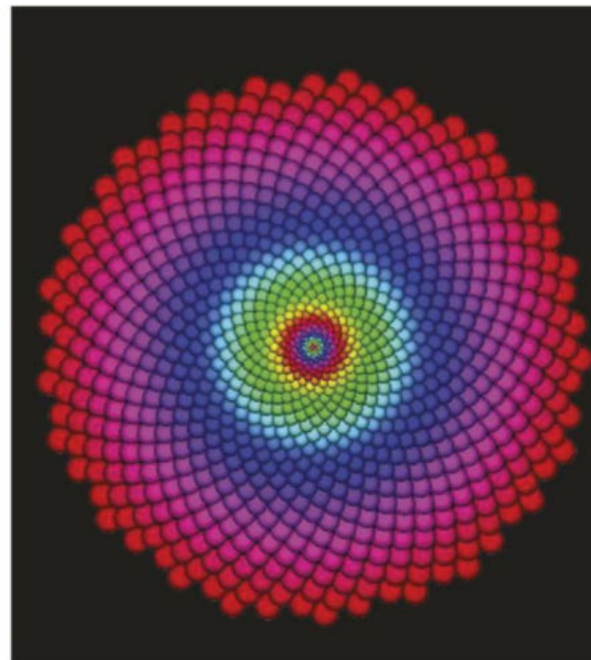
Let's think what has happened on Earth, and what may happen in the future. Technological civilisation emerged after 4.5 billion years, but within a few centuries it may have been surpassed by machines that spread into space – and they will have billions of years to develop further. So it may well be a fairly brief period in Earth's history during which intelligence is dominated by organic creatures, and a much longer future when it's dominated by machines. This therefore suggests that, if alien intelligence has emerged on another planet

via a similar route to what happened on Earth, we are unlikely to catch it in the brief organic stage – we're far more likely to catch it in the far longer post-organic stage.

What could we learn?

Biologists still don't understand how life began on the Earth. When they do, we'll learn two things. One is whether it's a rare fluke or whether we would expect the same thing to have happened in any environment like the Earth. Secondly, it will probably give us a clue as to whether the chemical basis of life has to be the RNA and DNA that our life is based on, or whether there could be quite different chemistries.

The Fibonacci sequence crops up a lot in nature – such as the spirals found on a sunflower – and could be used to communicate with aliens



➔ an international consensus on the matter has been reached. Details of the discovery will be spread rapidly to the general population through the usual media channels, and the person or persons who discovered the signal will tell the world themselves.

It is all well and good confirming an artificial signal from an alien race elsewhere in the cosmos, but if it is a deliberate message rather some eavesdropped technological hum, how will we know what it says? After all, they are unlikely to be fluent in any Earth language. But civilisations within a few tens of light-years of Earth would have received a few decades' worth of radio signals from Earth, so perhaps they could package up their message in a way they know we'd understand. Alternatively, it's been suggested that mathematics might be the language of choice for interstellar chit-chat. Initial contact could be made by beaming out a radio message encoding the list of prime numbers or the Fibonacci sequence. Once both sides know they both speak the same language – maths – you could use binary numbers to send more detailed messages such as pictures. So we'd search any potential message for mathematical structure.

Should we call back?

If we do find alien life and start up a conversation, what impact would that have on the wider population? One insight comes from a 1999 survey by The Roper Organization on behalf of the National Institute for Discovery Science (NIDS). When asked how they would cope psychologically with



A MESSAGE TO THE STARS

Should we be broadcasting our existence to the cosmos? Not everyone thinks it's a good idea...

When the Breakthrough Listen initiative was launched, so too was a sister project called Breakthrough Message. This is a competition to write a digital message to an alien civilisation, with prizes totalling \$1m (£660,000). However, there are no current plans to send these messages. "We pledge not to transmit any message until there has been a wide-ranging debate at high levels of science and politics on the risks and rewards of contacting advanced civilisations," say the organisers.

Stephen Hawking is one of many scientists to caution against sending unsolicited messages out into the Universe. Instead, the organisers want to inspire us to think about what information best represents humanity and how it might be presented in a way that an alien civilisation could understand.

So what should go into such a message? We can get some idea by looking at previous attempts at

communication. When the Voyager probes were launched in 1977, the craft carried with them gold-plated 12-inch copper discs containing sounds and images from Earth [see right]. Alongside recordings of birdsong, waves and thunder sits music by Bach, Beethoven and Chuck Berry. The images included depict our Solar System, DNA and how we reproduce. There's also a map showing our location with respect to several loud pulsars in the Milky Way. Voyager 1 may have left the Solar System, but it will be 40,000 years until it reaches another star system.

The Arecibo message, beamed towards globular cluster M13 on 16 November 1974, is another example. This short radio broadcast contained key information about the human race encoded into binary. The numbers one to 10 appear alongside information about DNA, a depiction of the human body and illustrations of the Solar System. But as M13 is

25,000 light-years away, the message won't be arriving soon.

That's another consideration – it takes an incredibly long time for signals to travel through space. Even travelling at the speed of light, it would be four years before any radio message we sent arrived at our nearest solar system. KIC 8462852, the star at the heart of the megastructures mystery, sits nearly 1,480 light-years away: any reply to a message we sent there today wouldn't arrive for 3,000 years. So a related problem is how to depict ourselves, our way of life and our technology in a way that will still be representative in the centuries to come. Some modern commentators have pointed out that the information despatched by Voyager 1 showed a civilisation dominated by white Western males. Perhaps the next time we choose to send information into space, it will be more representative of us all.



TOP: The gold-plated copper discs that the two Voyager probes carried into space in 1977

ABOVE: Mounting the discs, in their covers, on the Voyager probes. Both spacecraft carried identical discs

Aliens attack in 1996 blockbuster *Independence Day*. We have no way of knowing whether alien life would be friendly or hostile



➔ confirmed news of an advanced extraterrestrial civilisation, 32 per cent of respondents said they were "fully prepared to handle it" and 17 per cent said they would "rethink their place in the Universe". However, when asked how they thought *others* would respond, 25 per cent said "most people would totally freak out and panic" and 10 per cent said most others would "act irrationally and become dangerous to others".

"Much would depend on the contents of the message," says Forgan. Clearly, detecting the existence of advanced alien technology on a far distant planet is different from an aggressive message threatening imminent invasion. A 1997 survey found that 84 per cent of respondents believed aliens would turn out to be friendly rather than hostile.

Perhaps we can learn something about our reaction to extraterrestrial aggression from Orson

"A 1997 survey found that 84 per cent of respondents believed aliens would turn out to be friendly, not hostile"

WHAT ARE THE SYMBOLS ON VOYAGER'S GOLD DISC?

The hieroglyphic-like symbols engraved on the discs' gold-aluminium cover are meant to explain to any aliens that might find it how to access the information it contains

Outline of the cartridge and stylus – also sent on the Voyager craft – that are needed to play the disc

Plane view of the disc itself

Elevation view of the cartridge and disc

Diagram showing the position of Earth relative to 14 bright Milky Way pulsars, with the frequency of their pulses given in binary code

The top three diagrams here give technical information about the video signals on the disc and how to decode them, such as the number of vertical lines, the direction of scanning and the refresh rate

The fourth and final diagram shows that if the video has been decoded correctly, the first image that appears should be a circle

Diagram showing the two lowest states of the hydrogen atom. The vertical lines and dots indicate the spin moments of the photon and electron. The transition time from one state to another provides the clock reference used in all the other information stored on the disc

Welles' famous *War Of The Worlds* broadcast in 1938. The radio version of the HG Wells story was said to be so realistic that many people mistook it as factual and believed aliens were really invading. While reports of mass hysteria were overblown, the same cannot be said when a Spanish version was broadcast in Ecuador in 1949. Crazy crowds took to the streets and at least six people ended up dead.

Should the message not threaten imminent invasion, the thorniest question we'd have to confront is whether or not to send a return message. It's a topic that currently divides astronomers. "I was recently at a meeting of UK SETI scientists and there was a quick straw poll. The room was split exactly in half," says Forgan. He doesn't believe we should be sending out any kind of deliberate message into space. "I don't think it's a good idea to speak to someone when you have no idea who they are," he says. "I'm not convinced we should be advertising the human race at this point in our existence."

This is a particular issue if we've just eavesdropped on another civilisation without them explicitly sending us a message. They might have no idea of our existence. This hasn't stopped astronomers before, however. The Arecibo message, for example, was beamed towards the star cluster M13 in 1974. It contained fairly intimate details of who we are and where we can be found.

Now that our search for extraterrestrial intelligence is about to move up a level thanks to Breakthrough Listen, these are questions we are going to have to grapple with properly. There may be rules for how scientists should deal with any suspected signal; what the rest of us should do and how we're going to feel if that day ever comes is anyone's guess. But it's certainly an exciting time to be a citizen of the cosmos. **F**

Colin Stuart (@skyponderer) is an astronomy writer and author of *The Big Questions In Science*.

DISCOVER MORE

 *Is There Life On Mars: The 20 Big Universe Questions* by Stuart Clark (Quercus, 2014).

 Were we contacted by aliens in 1977? Read BBC iWonder's online guide to the Wow! signal, the Drake Equation and more. bbc.co.uk/guides/zqdbgk7

Contemporary reports of the panic caused by the 1934 *War Of The Worlds* broadcast were somewhat exaggerated



THE BITE THAT CURES

The evolutionary arms race between prey and predator has created some of the most deadly molecules on Earth. Now, scientists are repurposing these venoms to create the next generation of wonder drugs

WORDS: KATH NIGHTINGALE



Around 150,000 animal species have evolved the ability to produce venom. And, as Dr Zoltan Takacs says, it's evolution that has turned this venom into a such strong source of medicine →

To most of us, medicine comes from the chemist. There we can stock up

on blister packs of pills, tubes of ointments and bottles of innocuous-looking liquid. But the original sources of drugs can be much more exotic than your local pharmacist. The first HIV drug, for example, came from a sea sponge, while a heart disease drug is derived from the foxglove plant.

You can't get much more exotic than venomous animals and that's where scientists are turning their attention. Venoms are cocktails made up of between tens and hundreds of different toxins, usually proteins and smaller chains of amino acids similar to proteins called peptides, along with organic molecules, such as hormones, antibiotics and other compounds that are involved in the metabolic functions of living things. Venoms help animals to immobilise or kill prey, or neutralise predators in self-defence.

To qualify as venom, as opposed to poison, the toxin mixture must be 'injected' into another animal. Around 150,000 animal species have evolved the machinery to produce venom and inject it into prey. Some are familiar: snakes with their fangs, or bees and their stings. Others are less well known: the male duck-billed platypus with the venom-bearing spurs on its back legs; the toxic saliva of particular types of shrew; the beautiful but deadly cone snail releasing its harpoon-like proboscis into tiny fish on the seabed...

It's evolution that's made venom such a good source of drugs, says Dr Zoltan Takacs, a Hungarian-born scientist-adventurer who founded the World Toxin Bank. "Venom

"It almost gives you the luxury of tweaking some of the best pieces of molecules that evolution designed"



Dr Zoltan Takacs' work in animal venom led him to establish the World Toxin Bank

toxins are among the most potent and precision-targeted molecules on Earth," he explains. "From mankind's point of view, this makes venom toxins ideal templates for drug discovery."

Over hundreds of millions of years, the toxins in venoms have been honed to target highly specific components of their prey's vital bodily functions. Some toxins attack the nervous system, causing paralysis by interfering with nerve-to-muscle communication. Others prevent blood clotting, resulting in massive bleeding. Yet it's these same dangerous properties that could make them useful. Substances that interfere with the nervous system could make great painkillers, while blood thinning is a vital part of treatment for heart disease.

Don't try this at home

But this doesn't mean that doctors will soon be recommending you keep a few venomous snakes and spiders around the house. "Venom is a complex mixture of toxins," says Takacs. "You need to isolate a single particular toxin to have a safe therapeutic agent."

Using venoms as a source of drugs isn't a new idea. Ancient civilisations used venoms in medicines, and the first venom-derived drug of modern times became available in the UK in 1981. There are now around 20 different medications originating from animal venoms, says Takacs, targeting everything from heart disease to diabetes.

But only recently have scientists been in possession of the technology necessary to systematically search through venoms for likely drug candidates. Takacs collects venoms from around the world, often in remote



areas, to get his hands on new venom samples.

Using Designer Toxins technology, which he co-invented, Takacs fuses natural toxins from different venomous animals into a single molecule. This technique is used to create vast libraries of toxin variants, such as the World Toxin Bank, that can be screened against known drug targets to find toxins that have the highest promise to treat diseases.

"Imagine fusing pieces of snake, scorpion and sea snail toxins together and ending up with variants that are rooted in nature, yet have new biological properties," says Takacs. "It almost gives you the luxury of hand-picking and tweaking some of the best pieces of molecules that evolution ever designed."

With around 20 million venom toxins in nature left to explore, it looks like we may be seeing more and more drugs inspired by nature's powerful venoms in our bathroom cabinets. So where might they come from?

A patient allows his hand to be stung by a honey bee as part of a programme of bee venom therapy

The volume of venom found in a bee sting can be **up to 25 times greater than that of a wasp**

BEEES AND WASPS

TARGETS: HIV, breast cancer, skin cancer and rheumatoid arthritis

Of all the venomous bites, stings and punctures, the ones most of us will be familiar with are those from bees. Bee venom, though, contains compounds that could have uses as diverse as combatting HIV and helping to treat rheumatoid arthritis. More than half of the venom of honey bees is made up of a peptide called melittin. Despite its diminutive size, this toxin packs a mean punch – it's the cause of the burning sensation that comes along with a sting. In lab tests carried out by researchers at Washington University School of Medicine in the US, gold nanoparticles carrying melittin can puncture holes in the protective envelope of HIV without affecting human cells. While research is in its infancy, these nanoparticles could one day be part of a vaginal gel to prevent HIV transmission.

One of the biggest challenges facing cancer therapy is how to

ensure that drugs target only cancerous cells and not healthy ones. Researchers from the University of Leeds and São Paulo State University in Brazil are studying a toxin from the venom of the Brazilian wasp *Polybia paulista* that could do just that. It targets structures of fatty molecules on the outside of cancer cells, puncturing holes in the cells and causing vital molecules to leak out. Those same fatty molecules are found on the *inside* of healthy cells, which means that non-cancerous cells are safe from the wasp toxin's attentions. It's early days, though. The toxin has only been tested in the lab, so don't start welcoming wasps into your home just yet.

Melittin's puncturing properties could also see it being useful in cancer treatment. It's been shown to shrink tumours in mice with breast and skin cancers when delivered via nanoparticles. It can also block the inflammatory mechanisms in cells and animals with rheumatoid arthritis.

The toxin of the Brazilian wasp *Polybia paulista* is the ideal weapon against cancer since it leaves normal cells unharmed

SNAKES

TARGETS: blood pressure, blood clotting and chronic pain

If you were asked to think of a venomous animal, it's fairly likely that a snake would be the first that springs to mind. They're also probably the most studied among scientists in search of new drugs.

Many snake-derived drugs target the cardiovascular system. Workers on banana plantations who've been bitten by snakes often pass out due to severe drops in blood pressure. This led researchers to a peptide in the venom of the pit viper *Bothrops jararaca*. The drug based on it – blood pressure medication captopril – works by stopping the molecules that would ordinarily prevent blood vessel dilation, allowing them to widen and lower blood pressure. It was the first venom-based drug and continues to be one of the most popular medications on the market.

The southeastern pygmy rattlesnake, found in the US, has potent venom that stops blood from clotting and causes profuse bleeding. One of its toxins has been developed into a drug called eptifibatide that is used in people who are at risk of having a sudden heart attack. It stops platelets in the blood from sticking together, preventing the blood clots that can cause heart attacks and strokes. A similar toxin, from the venom of the saw-scaled viper, has the same target and is the basis of the drug tirofiban.

Another heart disease drug, currently in clinical trials, is cenderitide, which is made of a peptide from the eastern green mamba fused with another peptide from human blood vessel cells. And France's Institute of Molecular and Cellular Pharmacology is researching a toxin from the black mamba as a possible new painkiller, after studies in mice found it to be as powerful as morphine.

Vipers alter the level of venom depending on the victim's size

A saw-scaled viper is milked for its venom



CONE SNAILS

TARGETS: Chronic pain, Alzheimer's, Parkinson's, schizophrenia and lung cancer

These predatory carnivorous sea snails are found mainly in the warm Indian and Pacific Oceans and their toxins are already proving useful as painkillers. Their 'bite' comes from a modified tooth that is projected out of the snail's mouth and

injects venom into its prey, usually fish, instantly paralysing it. Once immobilised, the prey can be engulfed and digested by the snail.

While it's bad news for the fish, some of these same toxins have

shown painkilling effects in humans. There is already a drug on the market – the morphine-like ziconotide – which is used to treat severe chronic pain by administering it direct into the spinal fluid. It is a synthetic copy of a peptide from the venom of *Conus magnus*, also known as the magical cone.

Another snail toxin is being investigated by University of Utah

for its ability to affect nicotinic receptors in the brain which, as well as being involved in tobacco addiction, can play a role in Alzheimer's disease, Parkinson's disease, schizophrenia and lung cancer. And with each cone snail species producing its own distinct venom, there are probably plenty more where they came from.



One species, *Conus geographus*, is known as the '**cigarette snail**' because a human victim of its sting would only have **time to smoke a cigarette before they died**

SPIDERS, SCORPIONS AND CENTIPEDES

TARGETS: Cancer, muscular dystrophy, chronic pain and erectile dysfunction

Scorpion venom could be medically useful as a way of marking up brain tumour cells for surgery, as it's tough for surgeons to identify where a tumour ends and healthy cells begin. If they err on the side of caution, cancer cells get left behind. If they get too knife-happy, then healthy cells are cut out alongside cancer. Chlorotoxin, a component of venom from the cheerily named deathstalker scorpion, binds to tumour cells. Adding a fluorescent tag means that tumours 'light up', allowing a surgeon to clearly see their boundaries.

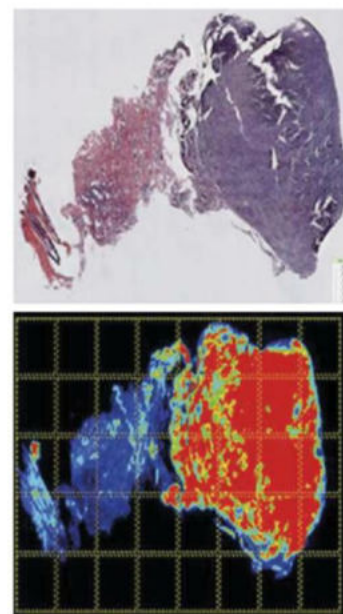
This 'tumour paint', developed by researchers at the Fred

Hutchinson Cancer Research Center in the US, has been tested in animals and is now being trialled in people.

Spider venom also appears to be a rich source of compounds for drug development, with toxins believed to have the potential to variously treat muscular dystrophy, chronic pain and erectile dysfunction.

Staying with arthropods, studies by researchers from the University of Queensland in Australia and China's Kunming Institute of Zoology point to a peptide from centipede venom having the potential to be a more effective painkiller than morphine, possibly without some of the side effects, such as addiction. The Chinese red-headed centipede, which produces the venom, is a pretty significant size, coming in at a whopping 20cm long.

The Brazilian wandering spider is the world's most venomous spider



ABOVE: These images of a canine soft tissue sarcoma show the use of 'tumour paint' to aid surgeons in the removal of cancerous cells.

LEFT: The deathstalker scorpion's venom is used to make tumour paint

PHOTOS: GETTY X3, ALAMY





SEA ANEMONES

TARGETS: Multiple sclerosis, rheumatoid arthritis, psoriasis and lupus

Native to the Caribbean, the sun anemone uses stinging cells in its tentacles to deliver venom to its prey, stunning small fish and other sea creatures before shovelling them into its mouth. Anemone venom peptides continue to pique the interest of scientists. One promising compound forms the basis of an experimental drug called dalazatide that's ready to undergo phase II clinical trials for treating autoimmune disease. Instead of suppressing the whole immune system like existing drugs, it very selectively blocks an ion channel in the particular type of immune cells that go haywire in autoimmune diseases such as multiple sclerosis, rheumatoid arthritis, psoriasis, and lupus. Kineta, a Seattle-based biotechnology company, is developing the drug.



The last known human fatality from a Gila monster bite was in 1939

LIZARDS

TARGETS: Diabetes

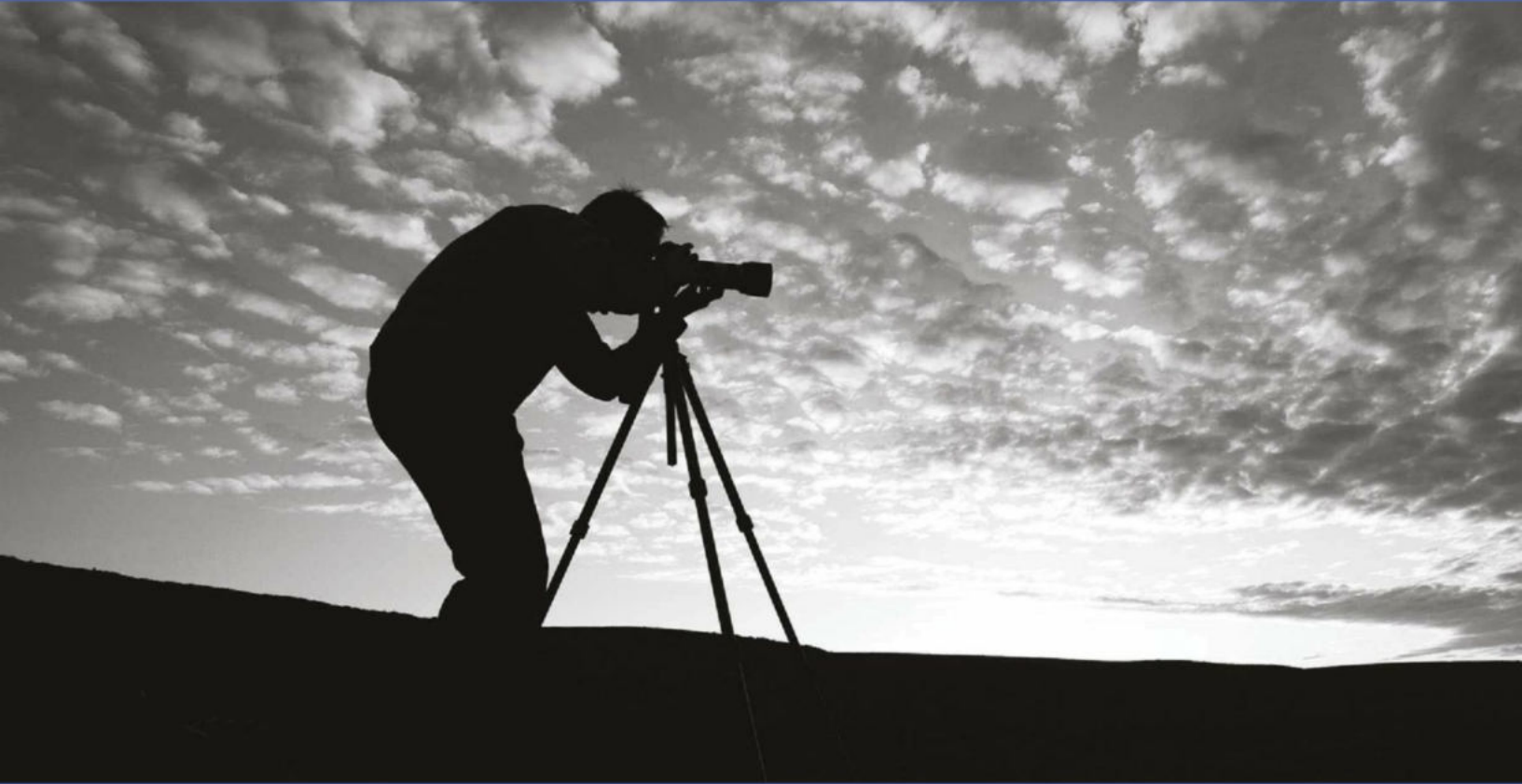
Heard of the Gila monster? These lizards are the biggest in the US and possess venomous saliva. They also claim an unusual ability to eat as little as three big meals a year, while managing to keep their blood sugar stable. Back in the early 1990s, researchers discovered a component in the lizard's venom that mimics the activity of a human hormone that stimulates insulin release when blood sugar levels rise. Exenatide, an injectable drug based on the toxin, helps people with diabetes maintain healthy glucose levels and even lose weight. **F**

Kath Nightingale is a freelance science writer with a background in molecular and cellular biology.

DISCOVER MORE

Visit the *BBC Focus* website to see our gallery of the most venomous animals on the planet bit.ly/WorldsMostVenomous

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ROBIN INCE ON... **ENTROPY**

“AS THE BATH WATER COOLS AROUND YOU, YOU’RE REMINDED OF THE UNIVERSE’S OWN HEAT DEATH”

W

hat’s the point of doing anything? We’re all doomed. Not only are we

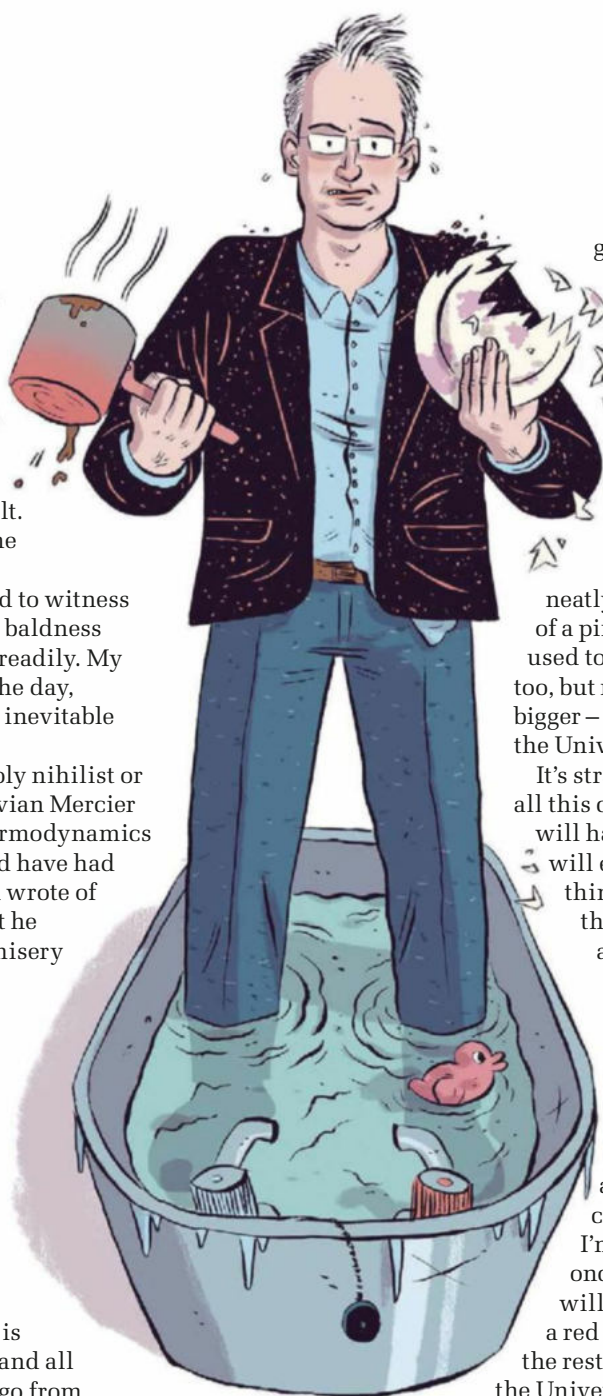
all doomed, but the entire Universe is doomed, its death notice issued in 1854 after a diagnosis by Herman von Helmholtz. The cause of death: entropy and the second law of thermodynamics.

I came across the idea as I started to witness my own decline into disorder: the baldness sped up and the skin flaked more readily. My cells were getting less orderly by the day, reminding me of the eventual and inevitable death of all things.

Entropy is a gift to the melancholy nihilist or weary existentialist. The critic Vivian Mercier wrote that if the second law of thermodynamics didn’t exist, Samuel Beckett would have had to invent it. In *Valis*, Philip K Dick wrote of his protagonist Horselover Fat that he “continued his long decline into misery and illness, the sort of chaos that astrophysicists say is the fate in store for the whole Universe... he forgot what event had started his decline into entropy.”

So what is entropy, exactly? George Porter, a former president of the Royal Society, famously opened a lecture on the second law of thermodynamics with: “We now come to the heart of the matter, the direction of the change.” What he was referring to is immutable law that the Universe, and all the energy in it, has a tendency to go from order to disorder. This is entropy. It tells us that ice cubes will always melt, that broken plates can’t fix themselves, and that the Universe that started with a bang may end in a whimper.

It seems simple. As you sit in the bath, shivering as the water around you cools but you’re too lazy to



get out, you’re faced with the same fate as the Universe: a slow heat death as your body temperature and that of the bath water reach equilibrium. On the other hand, if your water spontaneously got hotter, you’d be wary of wizardry – and the laws of physics would need a rewrite.

Still, it’s not all doom and gloom. Entropy tells us that the Universe had a beginning, too. Rewind time, and we can assume that it was all

neatly packed together – a Universe the size of a pinhead. Now look at the size of it. It all used to be hydrogen and helium around here too, but now the periodic table keeps getting bigger – the seventh row has just been filled as the Universe veers towards disorder.

It’s strange to think that, one day, the effect of all this cooling will be that the entire Universe will have a uniform temperature, and change will end. For a being that’s keen to order things, it’s odd that with our best current theories, disorder is inescapable. It’s almost an alibi for living in filthy squalor. “But darling, I’m just doing what the Universe tells me to. Don’t blame me, blame physics.”

Charles Darwin wrote that it was “an intolerable thought that [humankind] and all other sentient beings are doomed to complete annihilation after such long, continued, slow progress”. But I think I’m getting used to the idea. After all, once you’ve accepted the fact that Earth will be destroyed when the Sun swells into a red giant in a mere 4.6 billion years or so, the rest is a doddle. With the heat death of the Universe as a cosmic destination, all endeavours might ultimately be useless. But

while the best of our curiosity, joy and invention may not last forever, they’re still good ways to fill the time. **F**

Robin Ince is a comedian and writer who presents, with Prof Brian Cox, the BBC Radio 4 series *The Infinite Monkey Cage*.

NEXT ISSUE: MONKEY SELFIES



HOW TO MAKE YOUR OWN LUCK

*Is 2016 the year to get a new job? Or maybe move house?
With our guide, you can use maths to maximise your
chances of getting the best result*

WORDS: ROBERT MATTHEWS

1 Make better decisions

Some people are appalled by the idea of gambling – while ignoring the fact that everyone makes ‘bets’ every day, from guessing the quickest route to work to deciding whether or not to take a job offer. They’re all choices made in the face of uncertainty. Fortunately, there’s a branch of probability theory that helps cut through the complexity. Called Decision Theory, it’s a powerful way of identifying

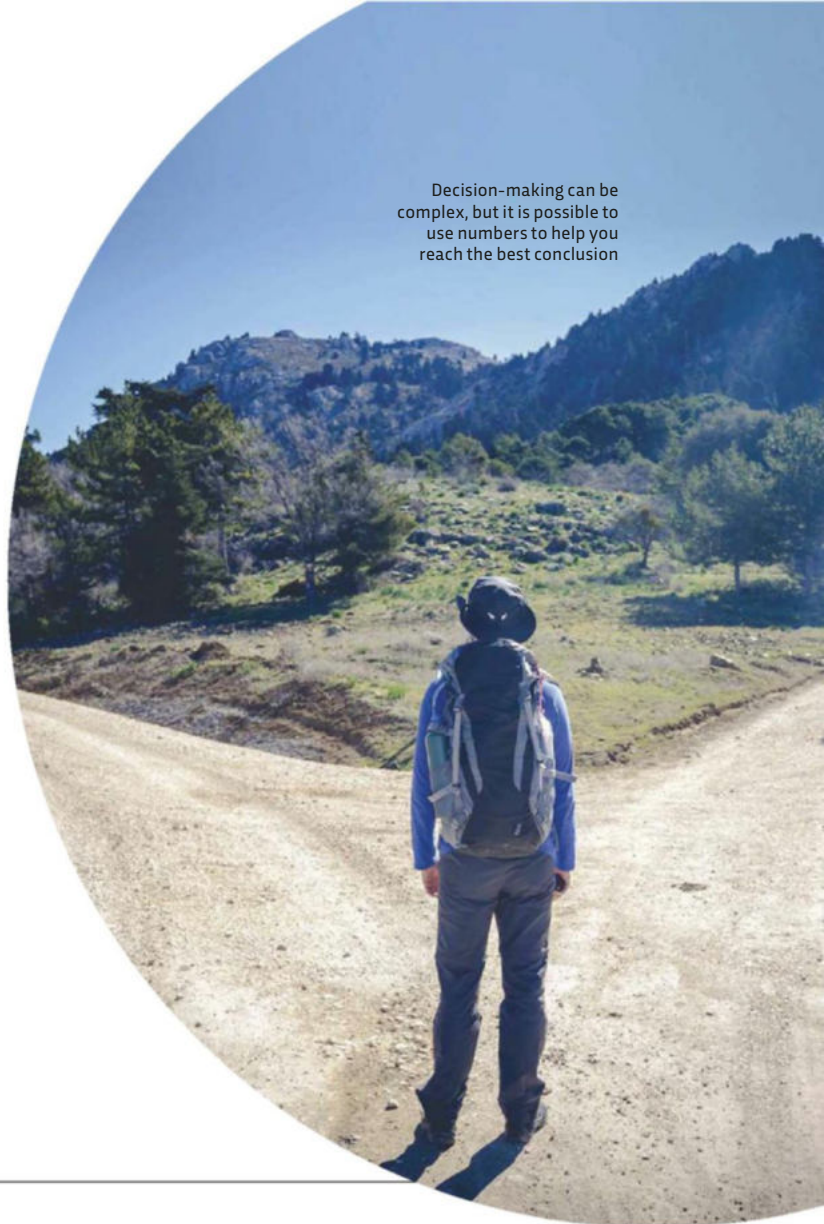
the choice most likely to give the best result.

To use it, we need to consider not only the chances of the various outcomes happening, but also the consequences in each case. Imagine you’ve heard rumours that a road may be built near your house. Should you move or stay? First, consider the consequences of moving or staying. As these will also depend on whether the rumours prove true or false, there will be four such consequences; you can rate each on a scale of, say, +10 (ideal) to -10 (awful).

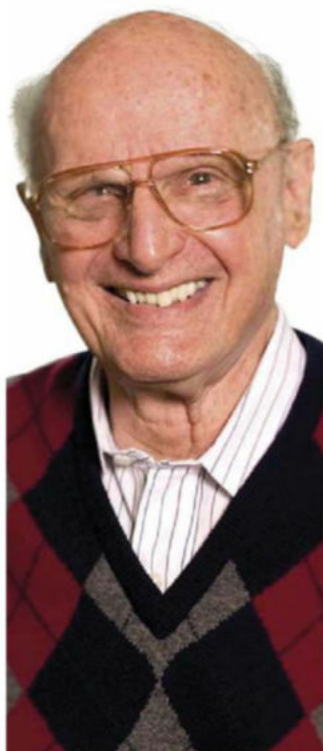
Now multiply each consequence by the chances of it coming to pass – remember that if there’s a 20 per cent chance of the rumour being true, there must be an 80 per cent chance of it being false. The results are the consequences you can expect in each of the four scenarios. Finally, add together the two consequences expected from staying put, and see if the result is bigger than the total expected from moving. If it is, the optimal decision is to stay. Otherwise, it’s time to move.

“Some people are appalled by the idea of gambling – while ignoring the fact that everyone makes ‘bets’ every day”

Decision-making can be complex, but it is possible to use numbers to help you reach the best conclusion



2 Play the financial markets: it's not rocket science



Numbers whizz Harry Markowitz ignores his own advice when he's investing cash

Back in the 1950s, economists developed Nobel Prize-winning theories for how best to invest money in financial markets. And to do it, they drew on the theory of probability. The result was Modern Portfolio Theory (MPT), which shows how to create a mix of stocks, bonds and other assets to get the best possible return for the lowest risk. By feeding in past performance data for each asset, the formulas of MPT reveal the relative proportions of each needed to achieve this optimal performance.

To pull off this miracle, MPT involves some fearsome equations that only rocket scientists might be expected to solve. But – like any attempt to model reality with mathematics – MPT makes assumptions, and the bad news is

they're not very realistic. A wealth of data now suggests that MPT simply cannot capture the real complexity of markets, making its conclusions dubious at best.

Even Harry Markowitz, the US economist who won the economics Nobel Prize in 1990 for developing MPT, admitted he ignored his own theory and simply split his investments equally between stocks and bonds.

The lesson of the laws of chance this time is: don't get too clever. When it comes to investment, history suggests most of us may do best by simply dividing our money among so-called index trackers that just follow entire sectors of the market – and then forget about them until we retire.

3 Have more fun in casinos

With global revenues in excess of \$150bn a year, casinos provide compelling proof of the benefits of turning a theorem about chance into a business model.

That theorem is the Law of Large Numbers, and it achieves the remarkable feat of allowing punters to believe they can win big, while guaranteeing the casinos a profit margin.

Take roulette, with its famous wheel of 36 alternating red and black number 'pockets'. As there are 18 of each colour, it seems obvious the chances of the ball landing in red or black and getting double your money back is 50:50. But look again: there's a green '0' pocket on the wheel (and a second marked '00' in US casinos). So the chances of landing on red or black are actually 18 in 37 (or 38 in the US) – slightly less than 50 per cent.

The prize on offer therefore doesn't quite compensate for the chances of losing. But the Law of Large Numbers does guarantee that over thousands of spins that tiny difference – the 'house edge' – becomes ever more reliable as a source of profit. On the way, however, there'll also be a few punters who have some luck and win a bit of that profit.

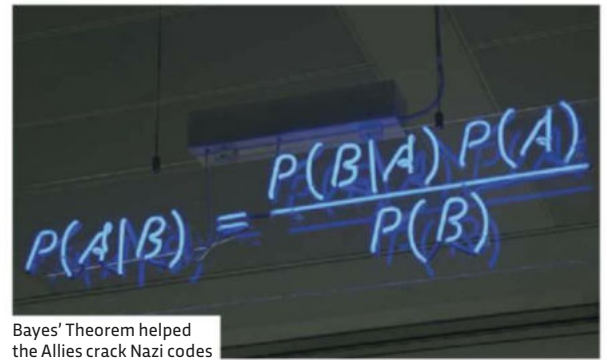
You can still make your own luck in a casino. Just choose games where the house edge is tiny, as in blackjack or single-zero roulette. Decide how much you are prepared to lose, and then avoid making lots of small bets – as these give the Law of Large Numbers the biggest chance of eating your money. Though your best bet of keeping hold of your cash at a casino is to avoid going there in the first place.

Avoid making lots of small bets – they will eat your money

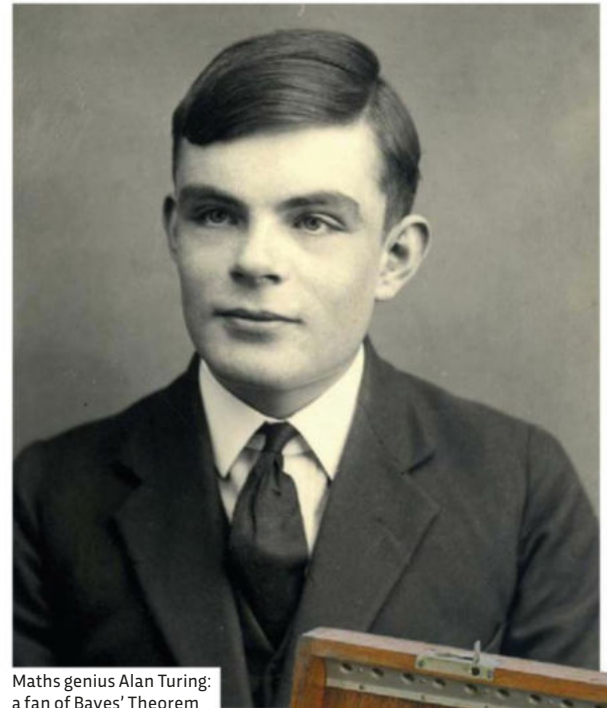
Want to swim through gold coins like Scrooge McDuck? Then bet big on casino games that offer a tiny house edge



At its peak, 10,000 people worked at Bletchley Park



Bayes' Theorem helped the Allies crack Nazi codes



Maths genius Alan Turing: a fan of Bayes' Theorem

4 Turn guesses into breakthroughs

When Alan Turing arrived at Bletchley Park in 1939 to break enemy codes, his boss thought the task was hopeless. The Nazis were using Enigma machines that scrambled messages in 15 billion billion different ways. Without an astonishing stroke of luck, what hope was there of hitting the right combination and revealing the messages? But Turing knew of an obscure formula that was up to the job – and used it to help win WWII.

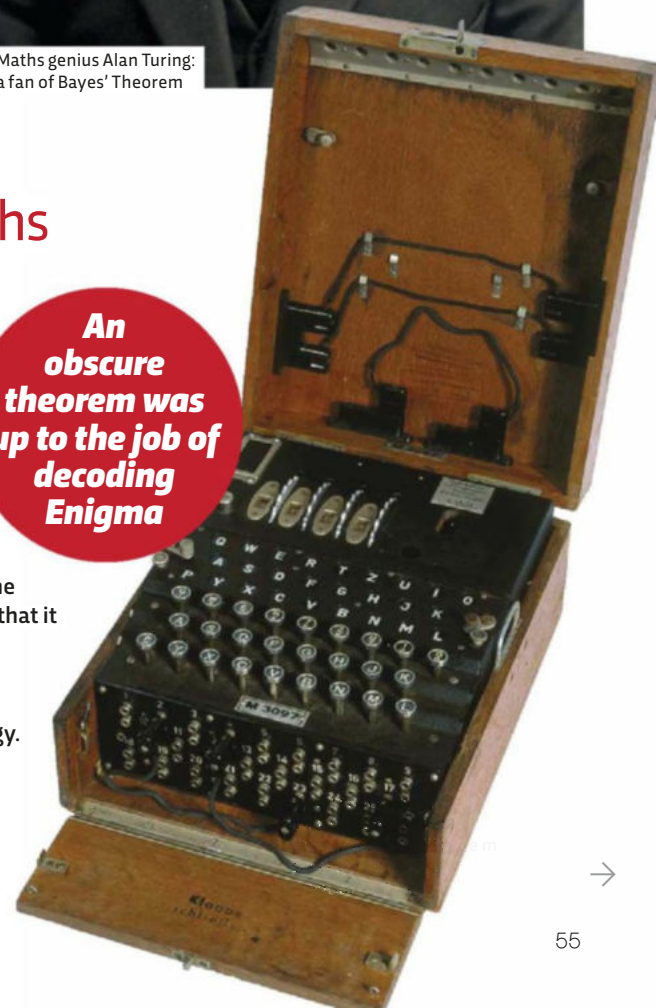
Known as Bayes' Theorem, it had emerged from attempts by mathematicians in the 18th Century to solve probability problems. Turing used Bayes' Theorem to take low-probability guesses about how Enigma messages had been encoded, combine them with evidence from intercepted messages, and produce slightly better guesses. Repeated over and over, the process homed in on the Enigma settings

with the highest chance of being right, thus 'breaking' the code.

Bayes' Theorem proved incredibly effective. By the end of the war, the codebreakers were routinely reading not only Enigma messages but also Hitler's personal communications, encrypted using far more complex machines. Turing's application of the theorem was deemed so powerful that it was only declassified in 2012.

Today, Bayes' Theorem is used to turn guesses into insight in fields ranging from medicine to cosmology. And it's now helping Turing's successors at the UK Government Communication Headquarters (GCHQ) to win the cyberwar against hackers and terrorists.

An obscure theorem was up to the job of decoding Enigma



5 Predict coincidences

We are all aware of the *Titanic* disaster of 1912, when the 'unsinkable' liner struck an iceberg and sank with huge loss of life because there weren't enough lifeboats.

Spookily, a fictional story about an 'unsinkable' liner that suffered the same fate had been published 14 years earlier. And the name of that ship? *SS Titan*.

Coincidences are intriguing, but they're also demonstrations of our shaky understanding of how chance works.

When the *SS Titan* story appeared, there were already concerns about icebergs, and about inadequate provision of lifeboats on big liners. As for the name, someone penning a

story about a huge liner is unlikely to name it *SS Midget*. In short, all these 'coincidences' aren't independent of each other, and are more likely to occur together than we'd expect.

But genuinely independent events can also coincide more often than you'd think. For example, probability theory shows that almost 90 per cent of football matches will include players with birthdays within a day of each other. The chances are so high because the birthdays of 22 players can be paired off in 231 different ways. Add in the fact we're not demanding an exact match either, and the chances of coincidences rocket upwards.

You can make your own luck out of that. Chances are your mates don't know it – so turn it into a bet while you're waiting for the kick-off.



Titanic's sinking is similar to a story published in 1898, but this isn't a remarkable coincidence

6

Beat the odds

From the winner of the Grand National to the member of One Direction most likely to go to rehab first, it's possible to bet on virtually anything these days. Millions of us do,

but even those who think they know what they're doing actually don't. Studies suggest 95 per cent of gamblers fail to make consistent profits.

So what are one in 20 people doing right? Put simply, they understand a theorem first proved over 300 years ago that shows when a bet makes sense.

The good news is that this 'Golden Rule of Gambling' is amazingly simple: only bet on events whose chances of happening are significantly greater than the bookmakers' odds suggest. For example, if a bookmaker is offering even odds on an event, don't make a bet simply because you agree that there's a 50:50 chance of winning.

Bookmakers' odds are specifically designed to give an optimistic view. As a result, if the event does come to pass, they'll pay out less

than the fair amount – and then pocket the difference as profit.

The Golden Rule of Gambling reveals that the only way to beat the bookies is to carry out in-depth research and find factors the bookmakers have overlooked. If this suggests the bookies have blundered and offered overly pessimistic odds, the Rule says the bet makes sense.

Now the bad news: simply checking past 'form' isn't enough, as the bookmakers do all that, and much more. Your research must be better than theirs – a big challenge. But it's not impossible: one top tip is to focus on 'novelty bets' like how many shots a team has on target. Bookmakers aren't so focused on nailing down the odds on these.

The lesson is simple: if you don't do the research, don't place the bet. **F**

Robert Matthews is visiting professor in science at Aston University, Birmingham. His new book, *Chancing It: The Laws Of Chance And What They Mean For You*, is published this month (£14.99, Profile Books).

"The only way to beat the bookies is to carry out in-depth research and find factors the bookmakers have overlooked"



It is possible to win big at the bookies, but you'll have to do all your research beforehand

GamCare is a registered charity that provides confidential telephone and online support and counselling to anyone affected directly or indirectly by problem gambling. See www.gamcare.org.uk or freephone: 0808 8020 133 (free calls from all UK landlines and most major mobile networks) every day from 8am to midnight.

CAN ANIMALS HELP US PREDICT NATURAL DISASTERS?





In the days leading up to an earthquake, snakes flee their dens and cows stop producing milk. Yet our best technology only gives us a few minutes' warning. What do the animals know that we don't?

WORDS: JO CARLOWE





Herd sourcing with ICARUS allows scientists to collect data in all kinds of different environments

“Watching animals for the clues they provide about the natural world has shifted from folklore to science”

T

he skill of observing animals to aid our survival dates back millennia. Nearly 6,000 years ago, the indigenous people of North America used their deep understanding of bison behaviour to devise an efficient way to hunt; they

frightened the herd into stampeding over a precipice and plummeting down to a butchering camp below.

In modern times, our interest in animal behaviour comes with new insights and terminology. ‘Herd sourcing’, for example, borrows from the word: ‘crowdsourcing’, but centres on using the collective intelligence of wildlife rather than people. Over the last few years, watching animals for the clues they provide about the natural world has shifted from folklore to science.

In 2013, for example, US scientists put to the test the ‘old wives’ tale’ that cows lie down when rain is on its way. The researchers measured the core body temperature of cattle and found that cows lie down when it’s cold and stand up when it’s hot to disperse heat. It may not accurately predict precipitation, but it does show a link between cattle behaviour and the weather.

Similarly, in September 2015, researchers studying public health records in Costa Rica found a connection between snake behaviour and weather patterns. The snakes were more prone to bite during the El Niño cycle.

Evidence that animals can be used as ‘intelligent sensors’ to predict imminent earthquakes also continues to grow. In 2014, researchers published a paper exploring unusual animal behaviours preceding the 2011 earthquake and tsunami that devastated Japan. As well as clingier behaviour from pets, the authors reported a fall in milk yields in cows within 340km of the epicentre a week before the earthquake struck. Stress impacts milk production, suggesting the cows sensed the earthquake before it happened.

Furthermore, in 2015, researchers published findings from a 2011 study using motion-triggered cameras in Peru’s Yanachaga National Park. The cameras captured changes in animal behaviour before the magnitude 7.0 Contamana earthquake hit. On a typical day the cameras recorded up to 15 animal sightings, but 23 days before the earthquake the number dropped below five. And then, in the week ahead of the event, it was down to zero. By recording the reflection of very low frequency radio waves above the sea surrounding the epicentre, the scientists detected disturbances in the ionosphere, which started two weeks

TRACKERS THROUGH TIME

In the 1900s, birds were tagged with string around their legs and handwritten identification codes. In the 1940s radar was used to study migrating animals, and by the 1950s sonar was being used.

In the last 30 years, scientists have started to track animals using satellite technology. In recent years, tracking transmitters have become smaller and more efficient thanks to improvements in battery technology and the use of solar panels. A swift, weighing just 42g, will carry a transmitter 'backpack' of 1.1g – the equivalent of a 70kg human carrying a 2.1kg weight.

Generally, 3 per cent of the weight of an animal is considered to be the upper limit and so far Sweden's Lund University has developed the lightest transmitters weighing just 0.6g.

Indirect techniques are used too. For example, Australian researchers are using 'proximity sensors' that emit a beam of electromagnetic radiation to monitor bats without the need for physical contact. These are used to model and assess the spread of disease.

Other non-invasive methods include: temperature and CO₂ monitoring inside beehives, counting footprints next to ant nests, using drones to collect periodic photos of animals, and positioning cameras next to nests and hives for use with image recognition software to count individual animals.

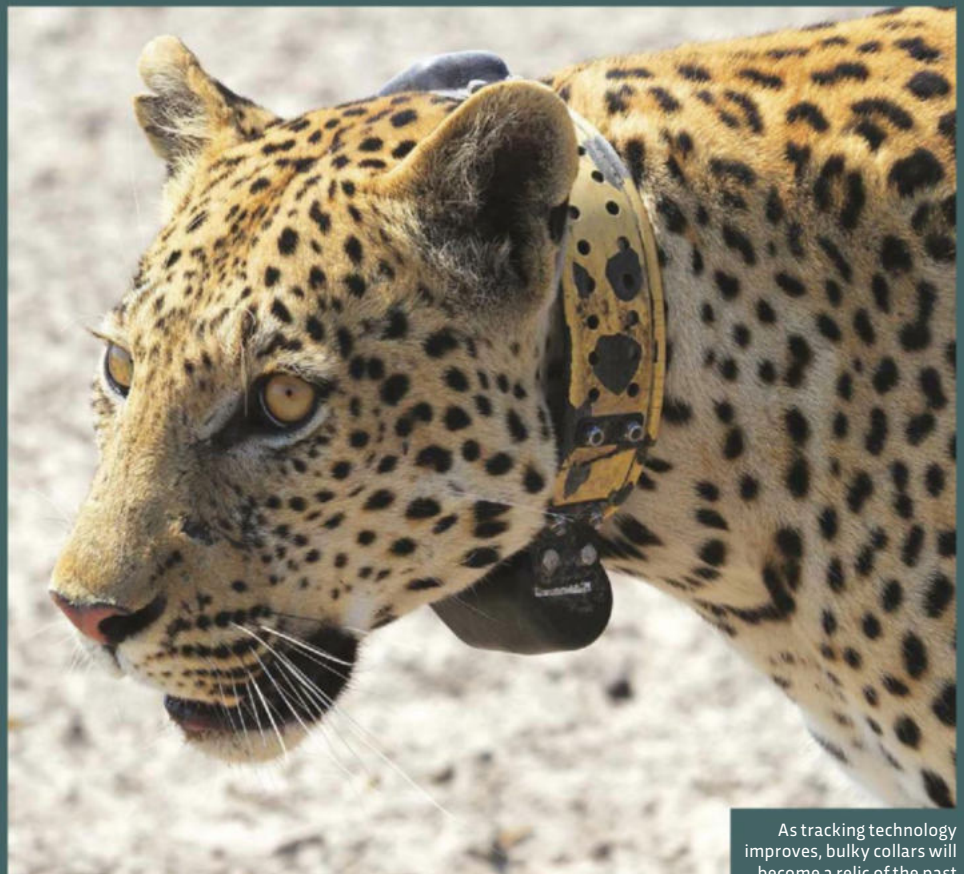
Crowdsourcing projects, such as Zooniverse, are also used. In this case, members of the public count and identify online images of animals that have been taken with motion-sensitive cameras.



Martin Wikelski attaches a tiny antenna onto the back of a song sparrow



Tagged monarch butterflies help us learn about their extensive migrations



As tracking technology improves, bulky collars will become a relic of the past

➔ before the earthquake. A large fluctuation, recorded eight days prior to the quake, coincided with the second significant decrease in the animals' activity.

Anglia Ruskin's Dr Rachel Grant, who led the experiment, cites 'positive airborne ions' – released when rock is subjected to stress – as likely having an effect on mammals and birds.

It is also likely that wildlife may be able to identify variations in atmospheric pressure, groundwater levels, gravity and chemical substances in the days or weeks prior to an earthquake taking place.

So if animals can act as an early warning system, how can we capitalise on this?

ICARUS takes flight

This year, scientists plan to raise the stakes in investigating these phenomena with the launch of the ICARUS Initiative – a system of observing wildlife from space.

ICARUS (International Cooperation for Animal Research Using Space) will see thousands of creatures fitted with tracking tags to allow radio-frequency communication with the International Space Station (ISS).

By globally tracking animal movements in real time, the ICARUS scientists believe they will be able to create an early warning system to predict natural disasters before they happen.

Furthermore, they will learn more about the spread of diseases, gain new insights into climate change, help conserve endangered species and develop better ecosystem services such as pollination, pest control and seed dispersal.

This is where ICARUS comes into play. This year, astronauts will fit a dedicated wildlife radio receiver/antenna onto the International Space Station (ISS). The device will enable long-distance tracking of animals in ways that have never previously been achieved.

Currently, when animals are tracked, data travels over mobile phone radio networks, which are full of dead zones where data cannot be transmitted. The ICARUS receiver will circle 320km above our planet, covering more than 90 per cent of the Earth's surface. As the ISS completes its orbit 16 times every 24 hours, the transmitters will never be out of transmission range for a significant length of time [see box]. This means they will reliably be able to communicate with the ICARUS equipment at the ISS, to regularly measure positions using GPS.

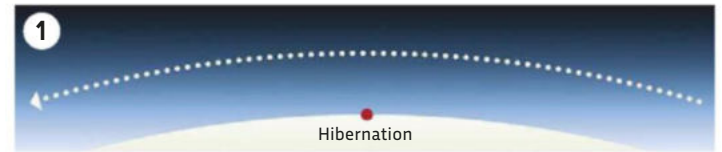
"ICARUS will work where cell phones do not – on the oceans, in deserts, in backyard woods, in the mountains and in agricultural fields," explains ICARUS director Dr Martin Wikelski.

The ICARUS team could then build algorithms that compare unusual animal movements or behaviours, such as the increased aggression of snakes or a drop in milk production in cows, to those already modelled in the system. This

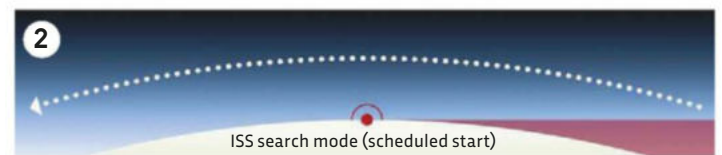


KEEPING IN TOUCH

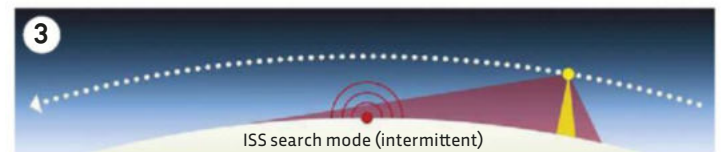
How the tags and ICARUS communicate



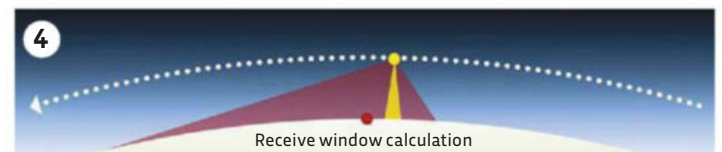
The tag (red dot) attached to an animal starts in hibernation mode, with low power consumption. It contains an internal timer that will cause the tag to 'wake up' when the ISS is expected to pass within range.



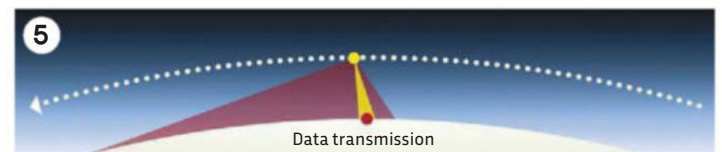
Once the tag has woken up, its receiver will start to listen periodically for the downlink radio frequency signal. This is transmitted by the ICARUS equipment aboard the ISS.



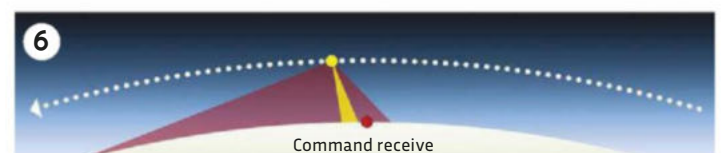
The intermittent signal will continue until the ISS downlink signal is picked up. Once the tag receives the downlink signal from the ISS, it extracts the most up-to-date data regarding the ISS's orbit.



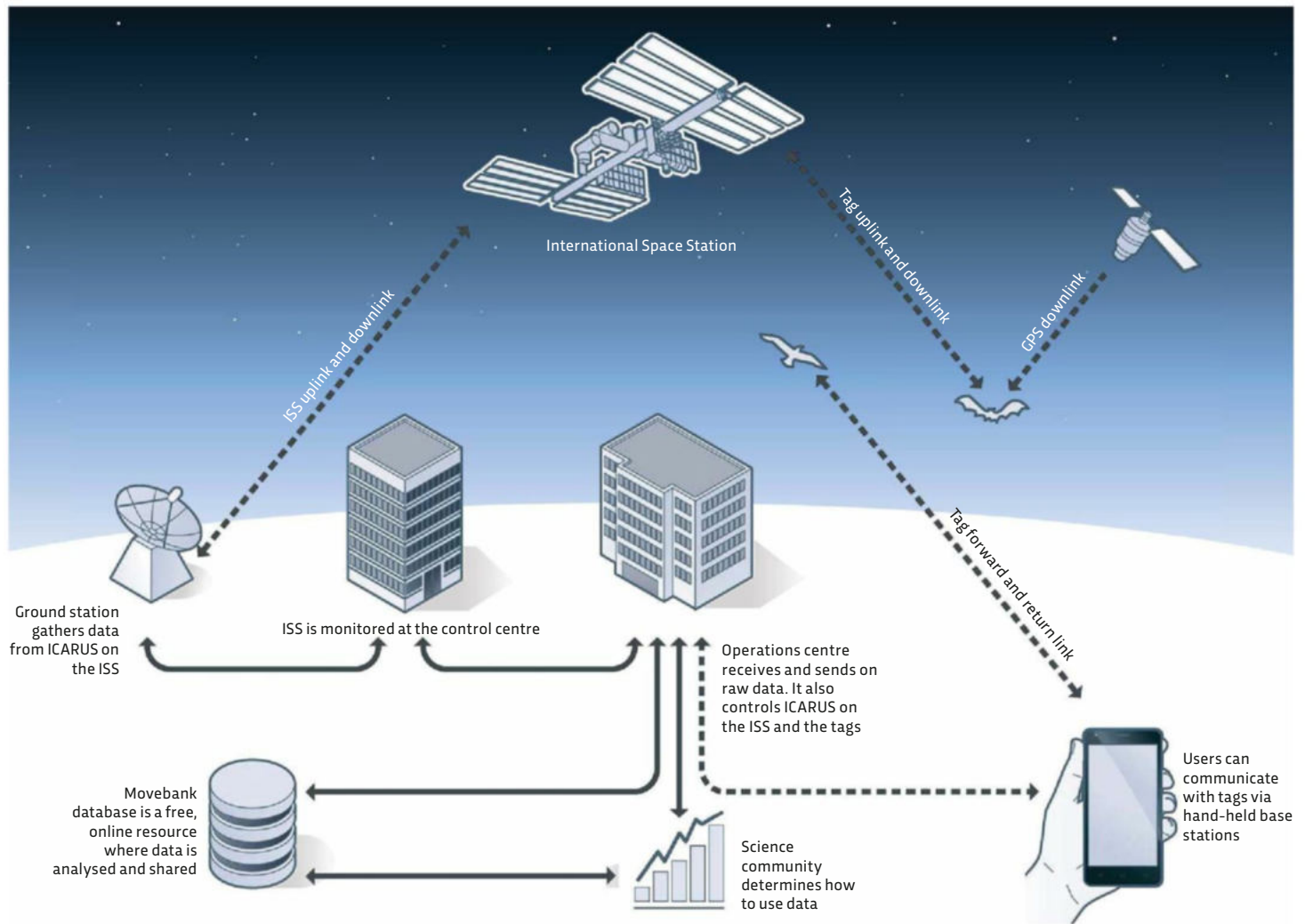
Once the tag has picked up the ISS orbit information, it will calculate its relative position to the ISS using its own GPS position on Earth. Using this data, the tag determines its presence within the ISS receive window.



After the anticipated receive window is reached, the animal tag transmits its stored location along with the sensor data to the ICARUS equipment on the ISS.



When the information has been sent, the tag will listen for any configuration commands sent from the ISS. It will then calculate the time period until the next ISS contact, before going back into hibernation.



Birds could be affected by ions released when rocks are stressed prior to an earthquake

→ would indicate an imminent earthquake, or other natural disaster. Ultimately, information of this kind could then be relayed to governments, NGOs and relief organisations to save lives on the ground.

ICARUS will inform in other ways too. About 70 per cent of epidemics, including bird flu and SARS, result from animal-human contact. A system like ICARUS could provide epidemiologists with vital information on where and how diseases spread.

Keeping tabs on the tags

In the first two years, at least 2,000 animals – ranging from cuckoos to sea turtles – will be tagged, rising to as many as 20,000 over time. As well as noting the animals' positions, the tags will include sensors to record altitude, diving depth, light intensity and any other areas of interest.

ICARUS is a CDMA (code division multiple access) system, a network that allows multiple transmitters to send information over a single communication channel at the same time. It is highly efficient and should allow for the future miniaturisation of the tags, the researchers say. Everything in CDMA is software-based, allowing easy upgrades of the system as the technology is refined. "The key is to have a very powerful computer up in the sky to decode the signals.

"The mission is to alter human understanding of life on Earth by giving animals an opportunity to communicate"

This is new and to our knowledge has not been done in any system before," explains Wikelski.

To start with, ICARUS will use transmitters that weigh around 5g. However, the company aims to shrink these down to less than 1g so that they can track insects.

"We are doing active research to find the best attachment places such as bracelets in orangutans, backpacks for birds or ear tags for mammals," Wikelski says. "In the future we don't want to see

animals with huge collars, but with a small ICARUS ear tag at most."

Scientists are experimenting with ways of following ever smaller creatures. In the UK, researchers tracked butterflies using harmonic radar, via a transponder inside a plastic tube. This was fixed to the insect's thorax with double-sided



Goats were tracked to see if their movements changed around volcanic activity

PHOTO: MAXCINE/EPD

sticky foam. The device tipped the scales at just 12mg (0.012g), just 8 per cent of the weight of the smaller species of butterfly used, and 4 per cent of the larger species. Generally, 3 per cent is the upper weight limit for tags, as anything above this may affect the animal's behaviour or movement.

Even minuscule creatures, such as zooplankton, can successfully be tracked with nanotechnology. Prof Lars-Anders Hansson, from Lund University's Centre for Animal Movement, uses quantum dots (Q-dots), microscopic fluorescent probes, for his work on the 1.5mm freshwater crustacean daphnia. However, the Q-dots are only visible within camera range, meaning they are currently only used to track organisms within aquariums.

Downsizing

"Nanotechnology is certainly being envisioned as we scale down the size of the tag," explains Wikelski. "However, this initially means making a chip that is much smaller and more efficient than current technology. We think ICARUS, being a new communication platform, will provide a lot of space and incentive for ingenious engineering around the world."

Interestingly, when it comes to animal movement ecology, some experts believe that political hurdles we face may prove more challenging than technological ones. Dr Yijun Yu, from the Department of Computing and Communications at The Open University, talks of "ethical, economic and social barriers". He is looking to use cloud computing, which is already used to track the course of aircraft, to monitor the speed and shape of animal movements, and calls for more international collaboration.


Efforts are certainly afoot. In tandem with ICARUS, a bio-logging society will form, made up of international experts, to share data on migratory patterns and anomalies in wildlife behaviour in order to safeguard animal and human lives.

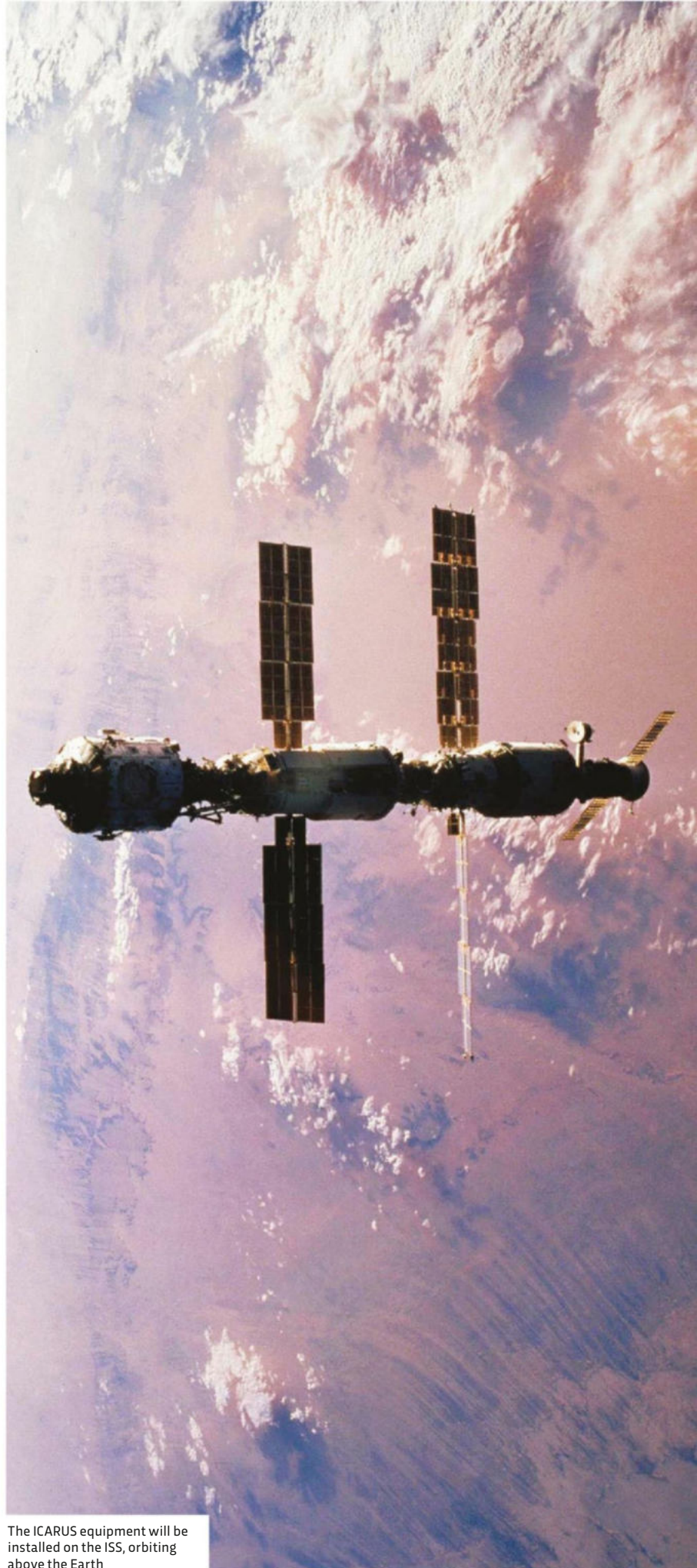
"The main mission is to alter fundamental human understanding of life on Earth by giving animals an opportunity to communicate with us," Wikelski explains.

If the ICARUS Initiative is successful, our relationship with the animal kingdom will be enhanced beyond anything we've seen before. It will give us a deeper understanding of how animals behave and could ultimately help us to save not only endangered species but human lives too. **F**

Jo Carlowe is a freelance science journalist and editor.

DISCOVER MORE

 Listen to the BBC Radio 4 series *World On The Move: Great Animal Migrations*, presented by Philippa Forrester and Brett Westwood at bbc.in/1g2Ma19



The ICARUS equipment will be installed on the ISS, orbiting above the Earth

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ROBERT MATTHEWS ON... RUBBISH THEORIES

"FROM ALZHEIMER'S CURES TO A THEORY OF EVERYTHING – SOME IDEAS SHOULD JUST DIE"

O

ver 40 years after it was first broadcast, Monty Python's Dead Parrot sketch still makes people laugh. On

the face of it, it's just a silly argument in a pet shop, with customer John Cleese trying to convince shop owner Michael Palin that a parrot he's just bought from the store is actually dead.

But like all the best comedy, it has achieved classic status because it taps into something familiar to all of us. The sketch is really about how some people will go to ludicrous lengths to deny evidence they don't like.

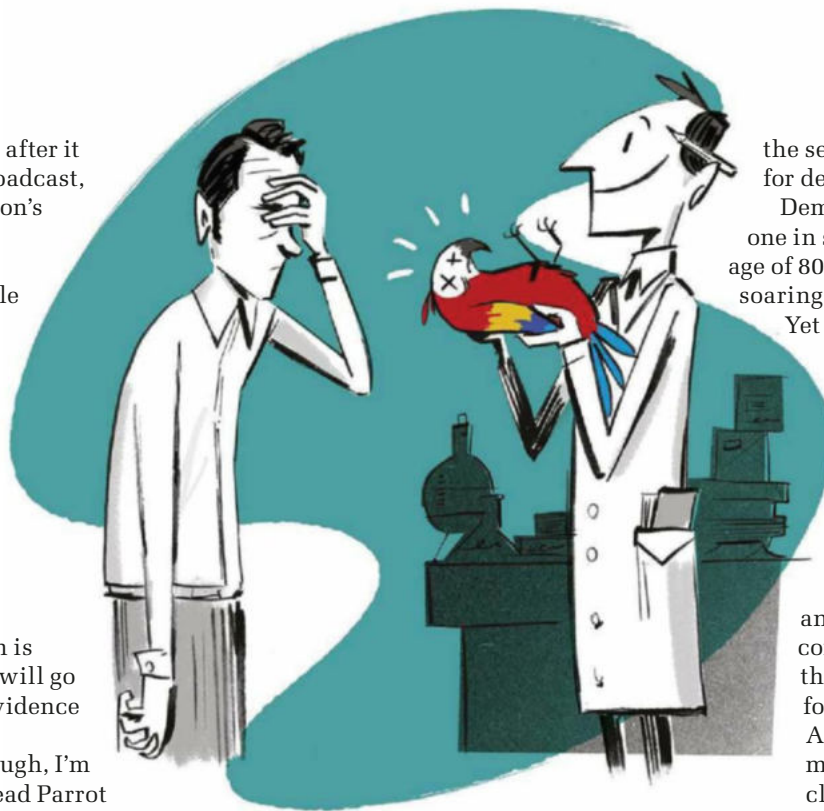
While it always makes me laugh, I'm beginning to worry that the Dead Parrot sketch also reflects an increasingly common feature of science: researchers insisting that a theory that seems pretty stone dead is really 'just resting'.

Since the mid-1980s, some smart physicists have been insisting that the Theory of Everything (ToE) is in sight: a single set of equations describing all the fundamental forces and particles.

The absence of any hard evidence has led some physicists to declare, Cleese-style, that they know a dead theory when they see one – and they're looking at one right now. But cheerleaders for the ToE reply: "No, no, it's not dead, it's resting. Remarkable theory, the Theory of Everything – beautiful symmetries!"

Fortunately, experiments at the Large Hadron Collider are about to do the equivalent of picking up the parrot and slamming it down on the shop counter. My bet is that the Theory of Everything will look pretty deceased. But I'd also bet some will still claim it's just stunned – and that the whole comedy will carry on.

Frankly, whether the Theory of Everything is dead or alive simply won't matter to most of us. But that can't be said about another enormous scientific quest that seems to be turning into the Dead Parrot Sketch:



the search for a cure for dementia.

Dementia already affects one in six people over the age of 80, and the numbers are soaring as people live longer.

Yet to judge by all the 'breakthroughs' making headlines, you'd think victory over this dreadful condition is just around the corner. Think again.

Take the recent announcement of a compound that attacks the sticky protein that's found in the brains of Alzheimer's patients. It made news, along with claims that a 'wonder pill' is in sight.

In reality, scientists have simply tested the compound on a few dozen mice, and found effects seen many times before, using substances that proved useless. Still, the quest must continue, right? Of course it should – but the failure to get anywhere with the sticky protein theory makes me wonder if it's actually a dead parrot.

I'm not alone, judging by the response of dementia experts to a recent editorial in the *Journal Of Alzheimer's Disease*. It said that despite 40 years of

effort and 100,000 research papers, "there is yet no hope, no effective treatment and no knowledge" of the cause. Still, many other researchers seem convinced the sticky plaque theory isn't dead, but 'just resting'.

It's been said that science progresses funeral by funeral. But can't the scientific community, which prides itself on putting evidence before all else, do better than simply wait for the old guard to drop off its perch? **F**

Robert Matthews is visiting professor in science at Aston University, Birmingham.

DISCOVER MORE



Listen to an *Inside Science* episode about the need for new treatments for Alzheimer's disease at bbc.in/1D0oex4

NEXT ISSUE: RESEARCH FADS



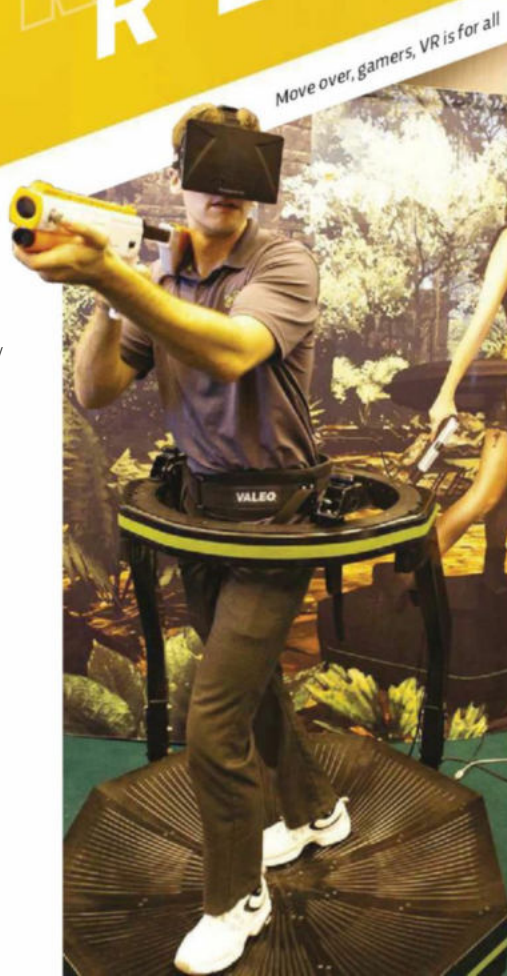


VIRTUAL REALITY GETS REAL

PHOTOS: PRESS ASSOCIATION, ALAMY ILLUSTRATION: ANDY POTTS

This year, virtual reality will finally come of age. The headsets won't just be worn by gamers: this revolutionary technology is set to change everything. From booking a holiday to visiting the doctor, our lives are about to get a whole lot more virtual...

Words: Jamie Carter



HOW VR WILL CHANGE... ENTERTAINMENT

Device makers are queuing up to produce VR headsets, principally for gaming. The frontrunner is Oculus Rift, which will go on sale in spring 2016. It attaches to a computer's USB slot, and comes with wireless Oculus Touch controllers to track hand movements. It works with Xbox One, while a competitor, PlayStation VR, will soon be launched, too. Other high-tech headsets include HTC Vive, Avegant Glyph, Samsung Gear VR and the Microsoft HoloLens. On the simpler side, the Google Cardboard supports a smartphone in front of your eyes. After all, modern phones broadly contain the same tech used by VR headsets. Cue VR apps for phones that are accessible to all.

However, VR is not just about gaming. "Films, sporting fixtures, gigs and events will be so much more immersive...the next best thing to actually being

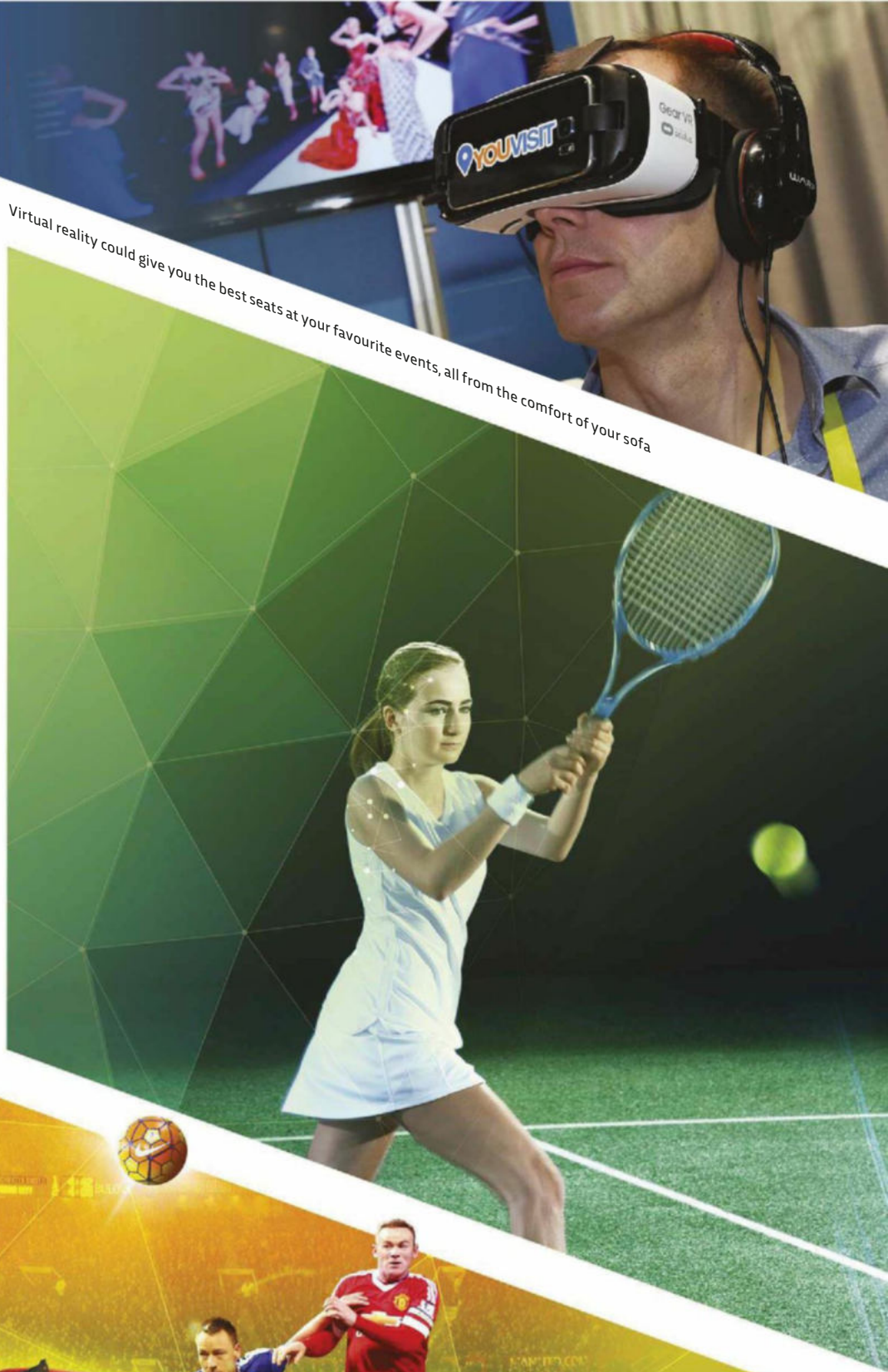
➔ there,” says David Haynes, a specialist in 3D mapping and VR. Oculus is owned by Facebook, which bought it for \$2bn in 2014. But why did Facebook want it?

“Manchester United selling the best seat in the house to every one of its supporters around the world, who could watch at home as if they were inside Old Trafford, would be worth significantly more to them than the current TV deals,” says Haynes. Will we one day watch TV only on VR headsets? Think tigers stalking your sofa, film sets you can walk around and having a front row seat to a live music concert.

However, first-generation VR headsets are passive and lack a sense of touch. Scientists at the Human Computer Interaction Lab of the Hasso Plattner Institute in Potsdam, Germany are working on Impacto, a wearable device directly connected to muscles in the arm (for virtual boxing) or foot (for virtual football) that mimics the sensation of hitting, and being hit, in a VR world. This is called haptic technology – the science of touch – and could trigger a flood of interest in simulating motion, heat and smell.

VR is about to get physical.

Virtual reality could give you the best seats at your favourite events, all from the comfort of your sofa





The British Museum uses VR technology to help visitors get a greater feel for times gone by

Desperate for a house with plenty of space for your book collection? Virtual reality lets you try before you buy

HOW VR WILL CHANGE... DAILY LIFE

School and learning

Education in the future will rely less on books and more on rich media – after all, we’ve already seen iPads take over the classrooms. VR can provide fully immersive experiences as well as simple 3D visualisations of objects. London’s British Museum now offers a VR tour of a Bronze Age roundhouse using headsets, and the chance to interact with 3D scans of its exhibits on a tablet. It comes in the wake of the Natural History Museum’s pioneering use of VR headsets for a *First Life* documentary shown last year.

Buying a house

Why look at pictures of a house when you can walk through it using a VR headset? Not only can potential buyers view a property without leaving their sofa, but the house doesn’t even need to have been built. As houses are planned and tested using VR by designers and architects, house-buyers could ‘move in’ virtually before deciding whether to buy. Harrods Estates has already trialled this using Oculus headsets.

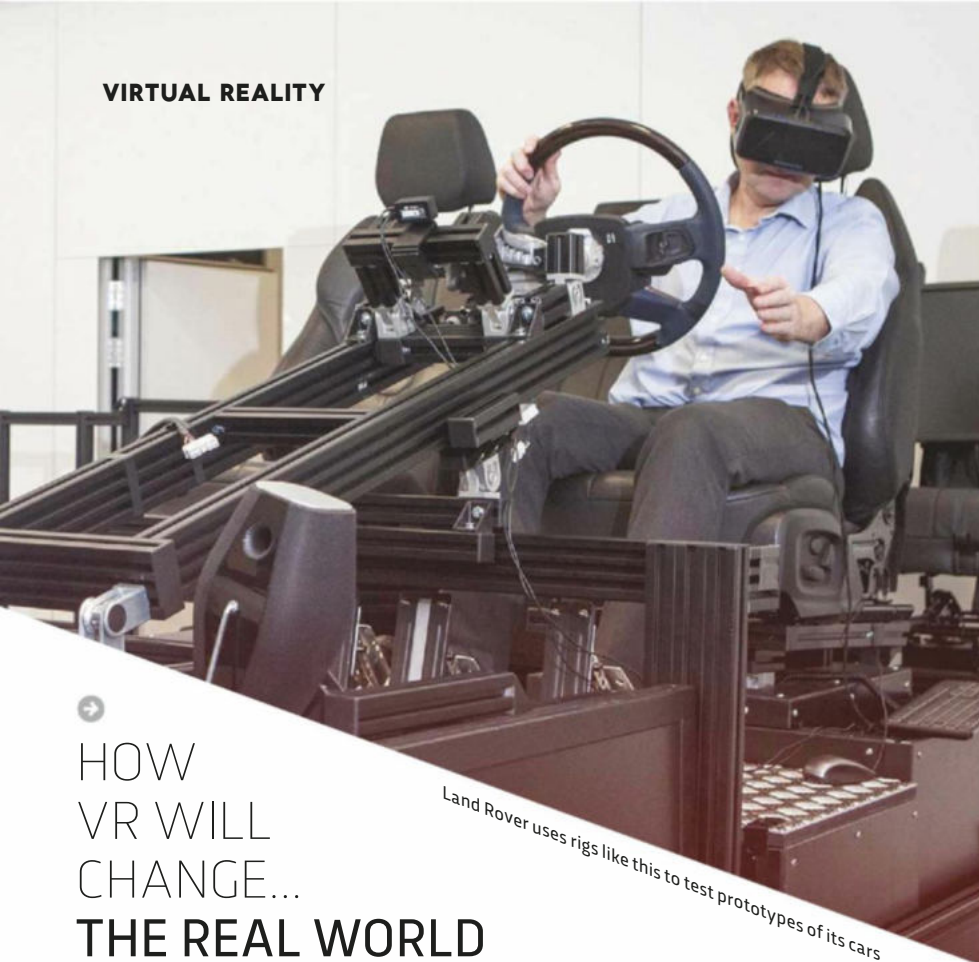
Going for a walk

We’ve had GPS devices for years, but now the Ordnance Survey has applied its mapping data to the virtual world to create an Oculus Rift game with Ben Nevis – Britain’s highest mountain – as the backdrop. The virtual tour is available as an app for phones and is designed to be used with Google Cardboard. “These technologies act as a passport for people who want to experience the sights and sounds of places they can’t get to, and as a planning tool for people preparing to visit these places,” says Haynes.

Sofas, but no TV?

Why watch a small TV when a VR headset allows you the full 360°? There’s no doubt VR headsets can revolutionise entertainment; they are cheaper than a TV and portable, too. However, it’s harder to predict whether the solitary concept of VR will be as appealing as watching TV with others.





Land Rover uses rigs like this to test prototypes of its cars

HOW VR WILL CHANGE... THE REAL WORLD

VR's ability to create immersive environments is a powerful tool for planners trying to solve transport issues.

Could longer trains reduce congestion at Canary Wharf train station? Go and have a look yourself. That's the idea behind the Visualisation Laboratory, a collaboration between Transport Systems Catapult (TSC) and Sheffield University. "Transport planners of the future will delve into interactive virtual worlds rather than interpreting data from spreadsheets or looking at images on a 2D monitor," says Martin Pett, technologist at TSC.

The Visualisation Laboratory uses high-end graphics processors to simulate huge crowds in virtual environments like train stations. Using a VR headset, transport planners can thus experience the results of their proposed solutions – perhaps a wider corridor, lifts or a new

bus terminal – from the traveller's point of view. It does away with the need for disruptive trials, and avoids costly mistakes.

"People within the environment interact as they would within the real world, steering and avoiding each other and the user," says Dr Paul Richmond from Sheffield University.

For now, the tech has helped create a detailed digital model of a train station, but there are also plans to use it to model driving behaviour on roads. Even the cars themselves are being shaped by virtual tech.

We visited Land Rover virtual design suite where engineers sit virtually inside their designs before they ever go near a factory. Testers can then try out their final designs in a virtual design cave, which creates life-size simulations of their cars.

HOW VR WILL CHANGE... TRAVEL

Up in the air

Last spring, Quantas offered Samsung Gear VR headsets to first class passengers, who could take a virtual 360° tour of airport lounges and destinations as well as watch 3D movies. Emirates has previously shown off a VR experience of its A380 aircraft on an Oculus Rift.

Try before you fly

Thinking of visiting a specific destination? Wouldn't it be good to check it out before checking in? That was the thinking behind a trial by travel agent Thomas Cook last year, which put Oculus Rift headsets into its shops for customers to see a 3D, 360° vision of the destinations and experiences on sale. VR specialist Visualise designed everything from a helicopter tour of Manhattan to a night at a restaurant in a Cyprus resort.

360° photos and videos

Panoramic photos are becoming more popular. The *Panorama 360 Cities* app is a great place to share and discover what places actually look like, but as phone cameras get more resolution and wider angle lenses, expect more 360° photos and even videos. Travel websites like TripAdvisor could even use them as part of reviews.

THE HEADSETS



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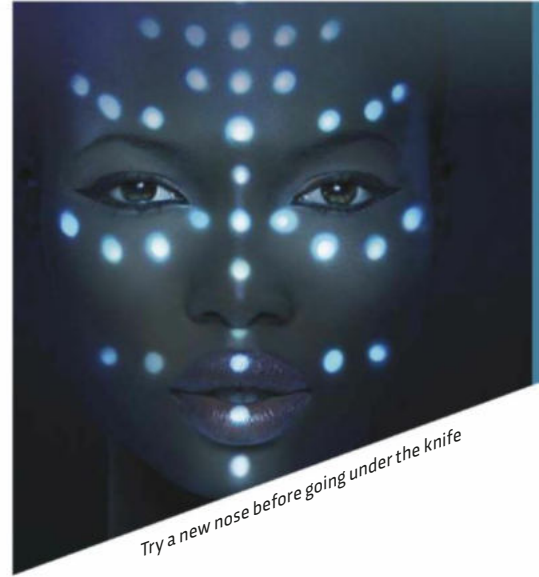
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HOW VR WILL CHANGE... US

How we look

Most cosmetic surgery procedures involve a big reveal when the bandages come off post-op, but why risk not liking the shape or size of your new nose, chin or breasts? New York-based practice bodySCULPT is offering its patients an Oculus Rift headset to experience how the procedure will look on a digital avatar of themselves.

How we think

Seeking to break down gender identity completely, BeAnother Lab's The Machine To Be Another puts two people of different sexes with their backs to each other, each in front of a mirror-screen and wearing a VR headset. If they move in-sync, they only see the other's body and gestures.

How we feel

Although the problem has so far been hushed-up by the technology industry, even the makers of Oculus Rift think 'visually induced motion sickness' is the biggest hurdle to VR going mainstream. Watching the virtual environment move while the wearer remains still creates a sensory conflict that can cause vomiting or headaches in some users. As simulators become more realistic, the problem could get worse. **F**



ZEISS VR ONE
£124.99
RELEASED JUNE 2015



FREEFLY VR
£49.95
RELEASED APR 2015

Jamie Carter is a freelance technology and travel journalist.

DISCOVER MORE



Watch a BBC clip about the future of virtual reality at bbc.co.uk/news/technology-30778807



See what it's like to ride a skateboard using virtual reality at bbc.co.uk/news/technology-34848856



Scientists are yet to agree on whether certain foods can be addictive in the same way as nicotine, alcohol or opiates

Are cookies as addictive as cocaine?

IT'S COMMON TO HEAR PEOPLE DESCRIBE THEMSELVES
AS 'CHOCOHOLICS', OR SAY THEY'RE 'HOOKED'
ON A PARTICULAR FIZZY DRINK. BUT IS IT REALLY
POSSIBLE TO BE ADDICTED TO FOOD?

WORDS: LILIAN ANEKWE



e're becoming more obese, as a society. Is this because some of us are becoming addicted to certain foods? One study, at Connecticut College in 2013, suggested that Oreos were "as addictive as cocaine," and certainly, some people who are overweight exhibit behaviours associated with addiction, such as an inability to avoid particular foods and a tendency to over-consumption at times of stress. But this is not true of all overweight individuals. So does 'food addiction' actually exist?

To answer that, we first need to understand what addiction is. The criteria for diagnosing substance addiction disorders in the *Diagnostic And Statistical Manual Of Mental Disorders* include developing a tolerance, having withdrawal symptoms and becoming dependent. The latest version, DSM-5, added: "craving or a strong desire or urge to use a substance".

The involvement of the brain is key to diagnosing addiction. Addiction affects areas of the brain that are linked to pleasure, reward and decision-making. It also affects neurotransmitters, the chemical signals used for communication between brain cells and brain

regions. Over time, memory of previous exposures to rewards (eg: food, sex, alcohol or drugs) leads to a biological response, such as cravings.

The best tool that researchers have for applying all this to food is the Yale Food Addiction Scale (YFAS). This 25-point questionnaire was developed in 2009 by Ashley Gearhardt, an assistant professor of clinical psychology at the University of Michigan. She believes addictive processes do play a role in eating-related problems.

"My research asks, how can we identify that group of people who are most likely to be showing an addictive response to food? To do that, I developed the Yale Food Addiction Scale. We're not

using body weight to identify people who could be addictive eaters; instead, we're using the same criteria we'd use for any addiction. This gives us a starting point, so we can look at whether there are behavioural, cognitive or biological markers in this group."

In one experiment, Gearhardt showed people pictures of 'treats' such as chocolate milkshakes, then gave them the real thing. She found that people who have more 'addictive-like' eating behaviour have more activity in brain regions linked to reward and desire when exposed to 'addictive cues' – the pictures of treats – than when they saw other images. They also have less of an inhibitory response in their brains once they have drunk the chocolate milkshake than after consuming other non-addictive foods.

"This indicates that this group of people is very reactive to cues in the environment that suggest these foods are available," explains Gearhardt. "Then, when they start consuming, the circuitry in the brain that usually allows us to apply the brakes and stop eating may not be working as well."

This same pattern is also seen in people with 'conventional' addictions. According to Gearhardt, this further strengthens the case for food addiction. In another study, Gearhardt's team recruited 500 people and asked them to complete the YFAS and to indicate which foods they were thinking of while reading particular statements. The usual suspects were at the top of the list: ice cream, chocolate, biscuits and sweets. According to Gearhardt, these are foods our brains have not really evolved to handle yet.

BIG PROBLEM

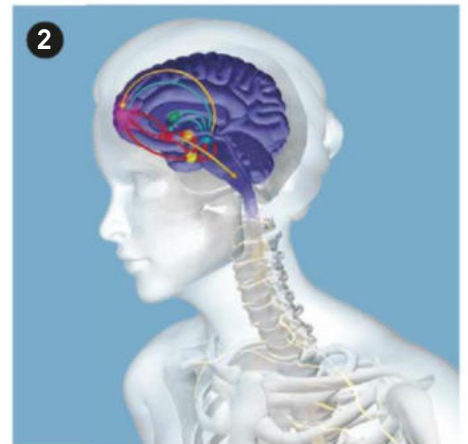
Our modern diets contain far more processed, sugar-heavy food than in previous generations, and it's showing on our waistlines. NHS figures show the proportion of obese adults rose between 1993 and 2013, from 58 to 67 per cent in men and from 49 to 57 per cent in women. This is set to rise even further, predicts the World Health Organization, to a whopping 74 per cent of men and 64 per cent of women in the UK by 2030.

However, food addiction studies have generally been conducted on animals, or snapshot studies in humans. And despite one support group for overeaters

"The circuitry in the brain that usually allows us to apply the brakes and stop eating may not be working as well"



- 1 People who completed the Yale Food Addiction Scale identified pizza as the most 'addictive' food of all
- 2 Sugar boosts dopamine production and triggers the brain's reward pathways
- 3 Modern diets contain more sugar than those enjoyed by previous generations
- 4 Ashley Gearhardt's Fast Lab explores eating behaviour in study participants



Some people report a relationship with sugary drinks (top) similar to that which alcoholics have with alcohol (bottom)



PHOTOS: ISTOCK X2

➔ having 6,000 members in six countries, including the UK, there still haven't been any comprehensive scientific reviews to study the issue. This is a problem that Dr Hisham Ziauddeen, a senior researcher in food reward processing at the University of Cambridge, feels undermines the idea of food addiction as a medical condition.

"The evidence for thinking food might be addictive, or that food addiction exists, is actually fairly weak," he says. "I wouldn't say it definitely does not exist – it's quite possible, given the breadth of symptoms that people with eating disorders describe, that a small group of people have problems with disordered eating that look very much like an addiction, and share the kinds of things that people with alcohol and drug addictions feel and experience."

But he remains unconvinced that the Yale Food Addiction Scale could identify these people, or convince 'doubters' like him. "People who score very highly on the scale also score very highly for some of the more conventional eating disorders. So the scale is measuring certain behaviours that we see with other eating disorders – but it's not actually capturing something distinct," he argues.

Some researchers go further, and say food addiction is a potentially dangerous public health message. Ian Macdonald, a professor of metabolic physiology at the University of Nottingham, feels this could be because it's difficult to reconcile an addiction with something that is essential to human life. Things like alcohol and drugs are, essentially, choices – eating is not.

SUGAR HIT

"I don't think the term 'food addiction' is particularly helpful, and I certainly don't think using the word 'addiction' in combination with specific nutrients like

fat and sugars, or foods like chocolate, should be encouraged," Macdonald says. "Everyone must eat to survive, so an addiction has to be something much more extreme than normal eating. It is not helpful to encourage the public to use these terms, because they will understandably expect it is similar to addictions to heroin, nicotine or alcohol, which is not true."

Even as a clinician, Macdonald says he is reluctant to use the term 'food addiction'. "I don't think health professionals should use the term unless they make it very clear exactly what they are talking about. The term 'eating addiction' is now being recognised in psychological

circles as being helpful in describing altered behaviour and cravings for specific types of food, or food in general. However, even this can be used inappropriately and over-interpreted."

It's possible to see how the concept of addiction might be counterproductive. Labelling 'food addiction' as a disease may create or reinforce a perception that excessive eating is something we are powerless to resist. If someone told you chocolate was addictive, or you were hard-wired to get hooked on junk food, would this strengthen or weaken your New Year's resolutions to eat healthily?

Prof Peter Rogers, who studies nutrition, behaviour and the brain's control of appetite at the University of Bristol, says labelling food addiction as a condition could have unpredictable effects. "A label like 'food addiction' is not trivial; it can have an effect that directly influences our experience of eating, of feeling hungry and wanting to eat."

His research, published in the journal *Appetite*, looked at how giving information about food addiction affects people's behaviour and preferences. In the study, 60 volunteers read different 'news stories' claiming scientists had either proven or disproven the existence of food addiction, before taking a taste test of healthy and unhealthy foods.

"Among people who had just read that food addiction was real there was an interesting split," Rogers explains. "Some people ate a lot, some people very little indeed. Which fits the theory that some people, having read the passage, thought 'I can't help myself' and succumbed, while others thought 'these foods are addictive' and refrained. So one implication is that the more people read about food addiction, the more they have a particular mindset when they are confronted with certain kinds of foods – and that can be helpful or unhelpful."

This may hint towards possible treatments for problem overeating. Having a concept of certain 'problem foods' that cause people to overeat and that should be avoided, could be used in a similar way to the complete abstinence model used to manage conventional addictions.

Before deciding on possible treatments, though, there needs to be a consensus as to whether food addiction actually exists, and if so, how it functions. As yet, the experts are far from agreed on these points. Clearly, certain people do crave certain foods, but we don't fully understand what drives these cravings, or what reward people get from eating the foods they crave. There's still plenty to chew over. **E**

Lilian Anekwe is a freelance science journalist, with a particular interest in health and medicine.

DISCOVER MORE



Listen to BBC Radio 4's *Constant Cravings: Does Food Addiction Exist?* at bbc.in/15Kkm4U

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SUSAN BLACKMORE

Susan is visiting psychology professor at the University of Plymouth. Her books include *The Meme Machine*.



DR ALASTAIR GUNN

Alastair is a radio astronomer at the Jodrell Bank Centre for Astrophysics at the University of Manchester.



ROBERT MATTHEWS

After studying physics at Oxford, Robert became a science writer. He's visiting professor in science at Aston University.



GARETH MITCHELL

Starting out as a broadcast engineer, Gareth now writes and presents *Click* on the BBC World Service.



LUIS VILLAZON

Luis has a BSc in computing and an MSc in zoology from Oxford. His works include *How Cows Reach The Ground*.

YOUR QUESTIONS ANSWERED

Email your questions to questions@sciencefocus.com or post to BBC Focus Q&A, 2nd Floor, Tower House, Fairfax Street, Bristol BS1 3BN

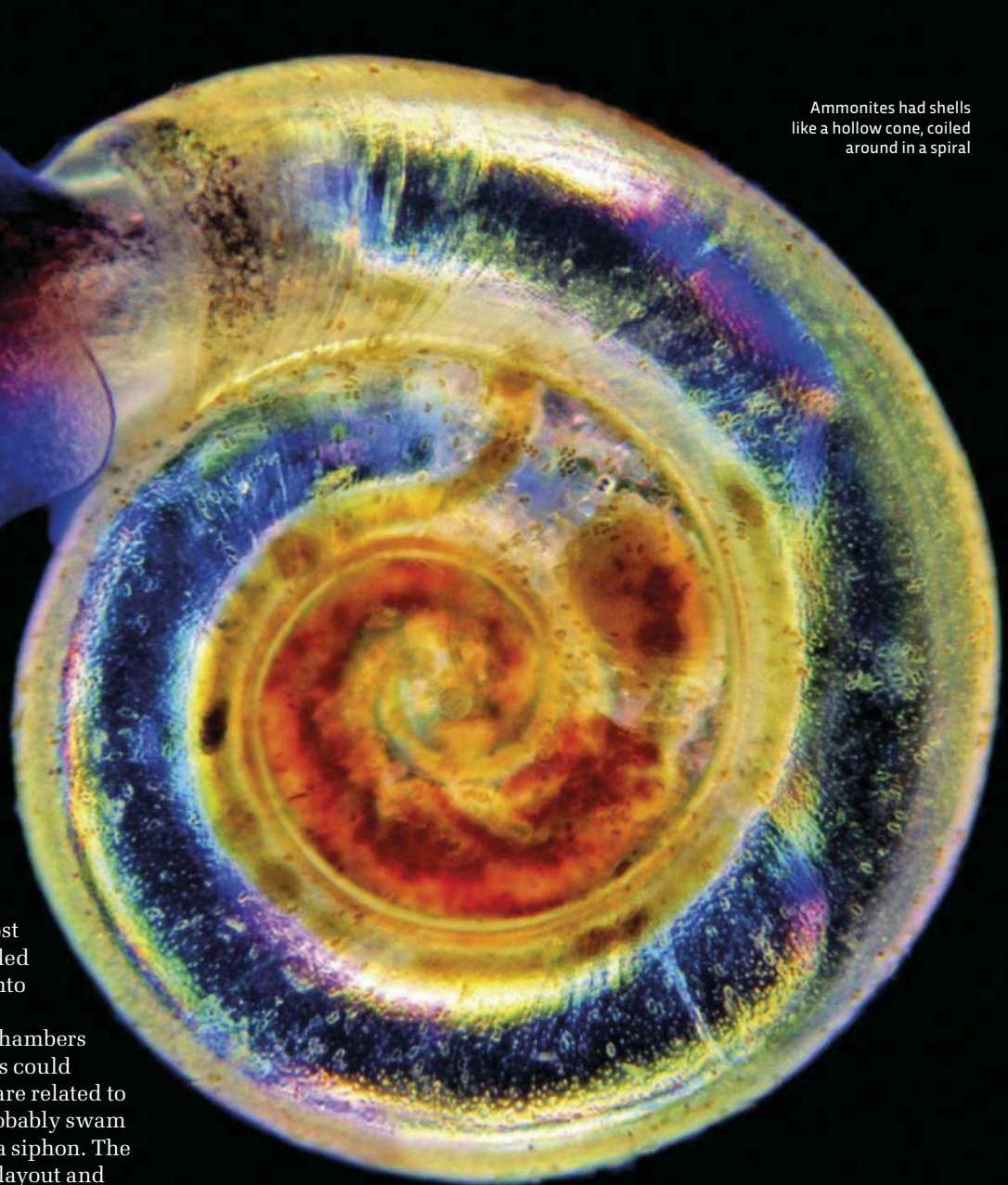
Ammonites had shells like a hollow cone, coiled around in a spiral

Could ammonites swim?

RICHARD BARKER, LEAMINGTON SPA

Ammonites are a group of extinct marine molluscs and they were able to swim. Their shells are divided into chambers and most of the animal's body sat in the outermost chamber, with just a single tube, called a siphuncle, extending backwards into the older chambers. The siphuncle diffused gas in and out of the shell chambers to adjust the buoyancy so ammonites could float in the mid-ocean. Ammonites are related to modern squid and cuttlefish and probably swam backwards by squirting water from a siphon. The modern nautilus has a similar shell layout and lifestyle, although they aren't closely related. **lv**

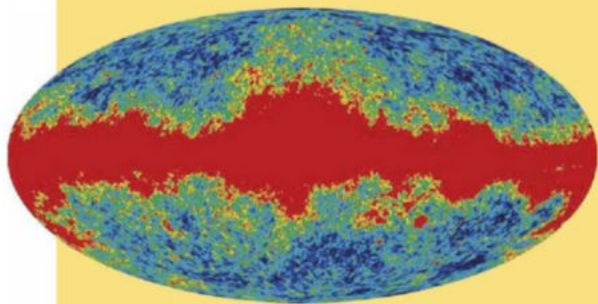
PHOTO: SCIENCE PHOTO LIBRARY



QUESTION OF THE MONTH

Does the Universe have an edge?

GERARD ROONEY, NEWRY



Cosmic background radiation suggests that the Universe is finite

Since light takes time to reach us from the furthest depths of space, and the Universe hasn't existed forever, there is a distance beyond which we cannot see. This distance is roughly 46 billion light-

years away and marks the boundary of the 'observable Universe'. Since we can never see the Universe beyond this, we have no real idea about how big it may be.

Some research suggests that the Universe is infinite. Other

WINNER!

Congratulations to Gerard Rooney who wins an EcoSphere self-sustaining aquarium (£199, eco-sphere.com).



IN NUMBERS

22 million

digits are in the largest known prime number – five million more digits than in the previous record holder

100

types of bacteria were grown from swabs taken from beards. Interestingly, a bacteria-killing microbe was also discovered

Why do cats hate water?

SUSIE ALLEN, BOURNEMOUTH

Cats groom themselves with constant regular licking, and this stops skin oils from building up on their fur. As a result a cat's coat is fluffier and less waterproof than a dog's, so they get colder and their fur feels heavier if they get wet. But not all cats hate water – the Turkish Van and Bengal are two breeds that like swimming. **lv**

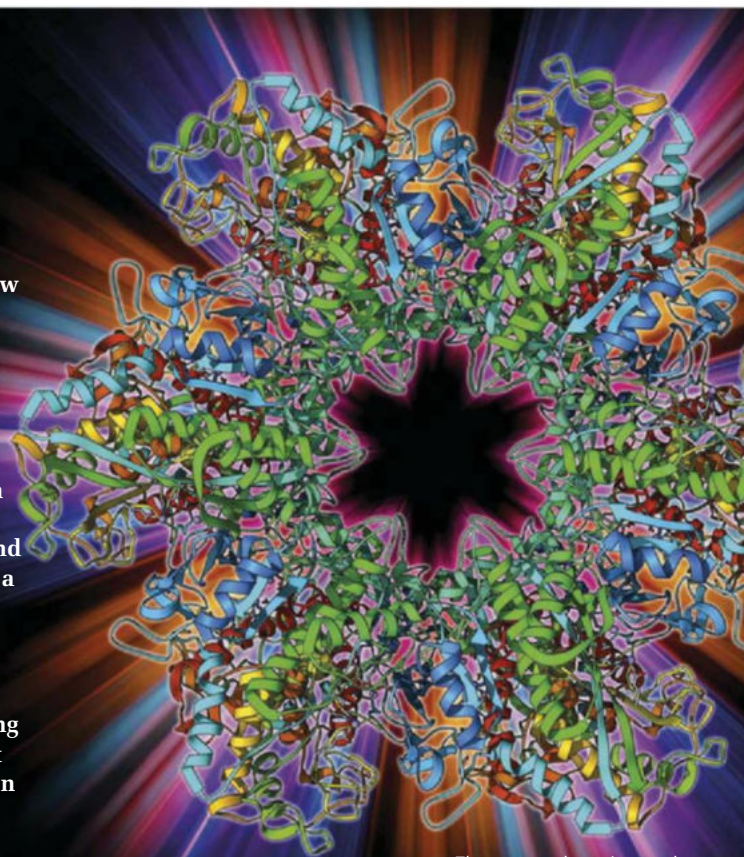


How old are the genes in humans?

HECTOR E QINTERO, PUERTO RICO

The genes in a modern human don't all date back to a single point in our history. When a new species evolves, it has almost exactly the same genes as its ancestors, with just a few crucial mutations that set it apart. The genes that gave early humans their larger brain size, for example, evolved around 500,000 years ago but we still share lots of genes with other primates and mammals. DNA is constantly mutating. The egg and sperm that originally created you probably contained 100 to 200 new mutations that weren't in your parents' DNA. Each of

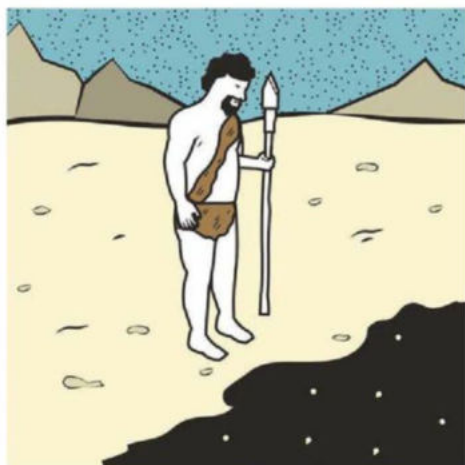
those mutations created a new gene, so you have quite a few genes that are only slightly older than you. At the other extreme, the oldest known functioning gene is the one that codes for the enzyme glutamine synthetase, which creates the amino acid glutamine from glutamate and ammonia. As this enzyme is a crucial part of the way cells make protein and remove excess nitrogen, natural selection has preserved it unchanged. Every living thing uses this same gene that first evolved more than two billion years ago – before even the first cells with a nucleus emerged. **lv**



The enzyme glutamine synthetase has a vital role in cells. It is coded for by the oldest gene

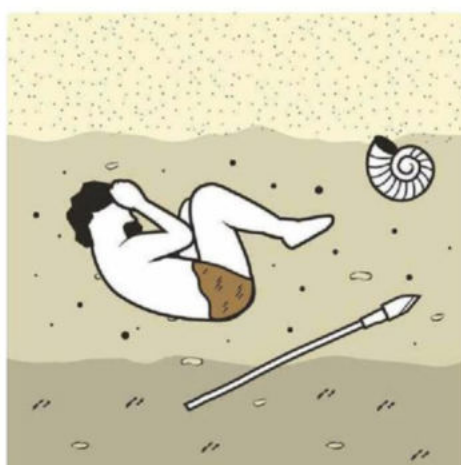
THE THOUGHT EXPERIMENT

HOW COULD I BECOME A FOSSIL?



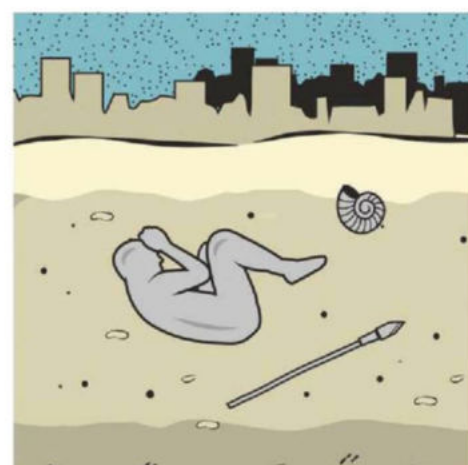
1. PICK THE RIGHT PLACE TO DIE

Fossils form best in oxygen-starved environments that keep out bacteria. These conditions also encourage the chemical reactions that replace your body's soft tissues with hard minerals. Drowning in a stagnant lake is a good bet, or a cold sea.



2. GET BURIED QUICKLY

A layer of sediment keeps out scavengers and protects your skeleton from being scattered by currents. Shallow seas are good because a constant, gentle rain of dead plankton and sediment is washed down by rivers. It will take at least 10,000 years to fossilise you.



3. GET DISCOVERED

If you want to be found as a fossil, pick a place where the motion of tectonic plates will lift you above sea level, so erosion can start peeling away the layers of rock above you. If the rock below you is crumbly, so much the better – it will collapse into cliffs that expose fossils faster.

Do we still get vitamin D from sunshine when we sit behind glass?

JEFF HIBBARD, BIRMINGHAM

No. Ordinary window glass is only transparent to wavelengths of light longer than 330 nanometres. But to synthesise vitamin D, we need UVB wavelengths between 270 and 300nm. You can get a suntan through glass, but to make vitamin D you need to be outside. On the other hand, at least 50 per cent of UVA can penetrate through glass, so skin ageing can still take place. **LV**



HEAD TO HEAD



GRIZZLY BEAR



AFRICAN LION

360	WEIGHT (kg)	190
48	TOP SPEED (km/h)	80
751	BITE FORCE (N)	1,768
30,000	APPETITE (calories/day)	9,000
1	HUMANS KILLED PER YEAR	250

It's a popular match-up in pub arguments, although it's unlikely that the two animals would ever meet. A grizzly can weigh almost twice as much as an African lion, so they can

soak up more damage. A bear's claws are larger, and it also has a much stronger bite force. The lion is faster over short distances though, so its best bet would be to make a run for it.

Why does stubbing your toe hurt so much?

TOM REYNOLDS, KING'S LYNN

Toes, like fingers, have lots of nerve endings so they can sense the texture of the ground underfoot and maintain balance. They are also at the end of a long and heavy pendulum – your leg. So when they strike something, they strike it fast and hard and there are lots of pain receptors anxious to remind you to be more careful next time. **LV**



PHOTOS: GETTY X3 ILLUSTRATION: PHIL ELLIS

What are the physiological effects of too much g-force?

ADHUAY RAO, BY EMAIL

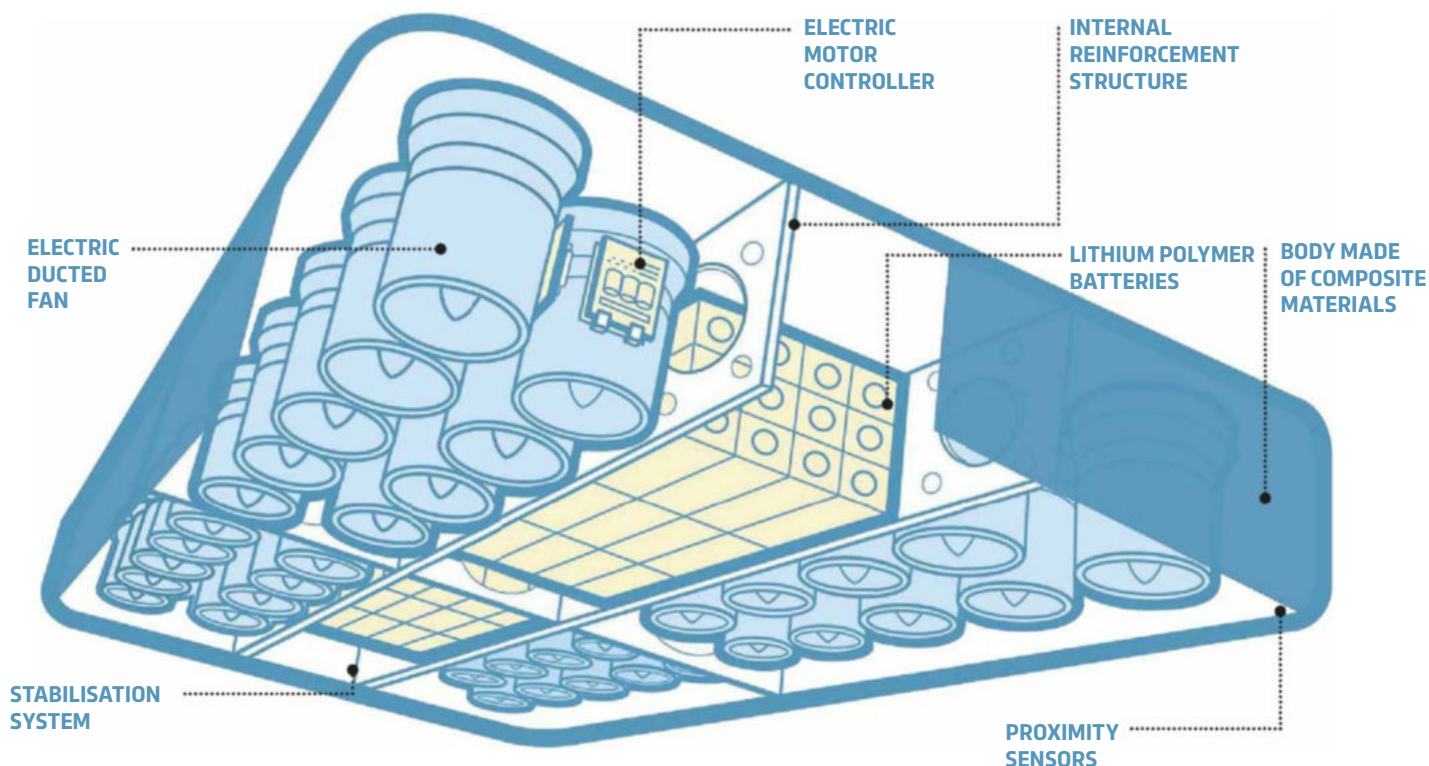
It depends on the direction. An upwards acceleration of about 5g is enough to overwhelm the ability of your heart to pump blood to your brain. This causes oxygen starvation and you will black out within a few seconds. Downward, or negative, g-force is even worse.

The blood pools in your head, your face swells up and your lower eyelids are forced over your eyes. This is called 'redout' because all you see is the light shining through your eyelids. At negative 3g, the blood can't get back to your lungs to re-oxygenate, so you pass out. **LV**



HOW IT WORKS

THE ARCABOARD



Unlike some, ahem, 'hoverboards' on the market, this one is not powered by wheels and you don't even need a special track to use it. The 36 fans embedded in the Arcaboard provide a combined 272 horsepower and create almost 2,000N of downward thrust to lift it into the air. The Arcaboard uses a system of gyroscopes to maintain stability in flight.

The whole system synchronises to a smartphone via Bluetooth and can be used in two different modes: in the first mode the rider simply stands on the board and controls the board's movement with their phone; in the second, just the elevation is controlled by the phone leaving the rider to control the movements of the board by tilting it forwards and backwards.



SPECIFICATIONS

SIZE: 145 x 76 x 15cm
WEIGHT: 82kg
NUMBER OF DUCTED FANS: 36
TOP SPEED: 20km/h (12.5mph)
MAXIMUM ALTITUDE: 30cm
NOISE LEVEL: 92dB
ENDURANCE: 6 mins
MAXIMUM RIDER WEIGHT: 110kg

Could fish be conscious?

ANDREW SMITH, LONDON

Consciousness is a mystery. It's impossible to know what an animal, or even another human, is experiencing. We cannot ask a fish, we can only observe it. Fish can learn and have long memories. When stressed by being held in a net, they display 'emotional fever', meaning they increase their body temperature. So do they feel pain? They have some brain structures similar to ours and also have opioid receptors. And if given anaesthetics, they are less affected by noxious stimuli. **SB**



Don't go teasing your pet fish – the three-second memory stereotype is a myth

Why do some people take more risks?

LESLIE O'BRIEN, HEREFORD

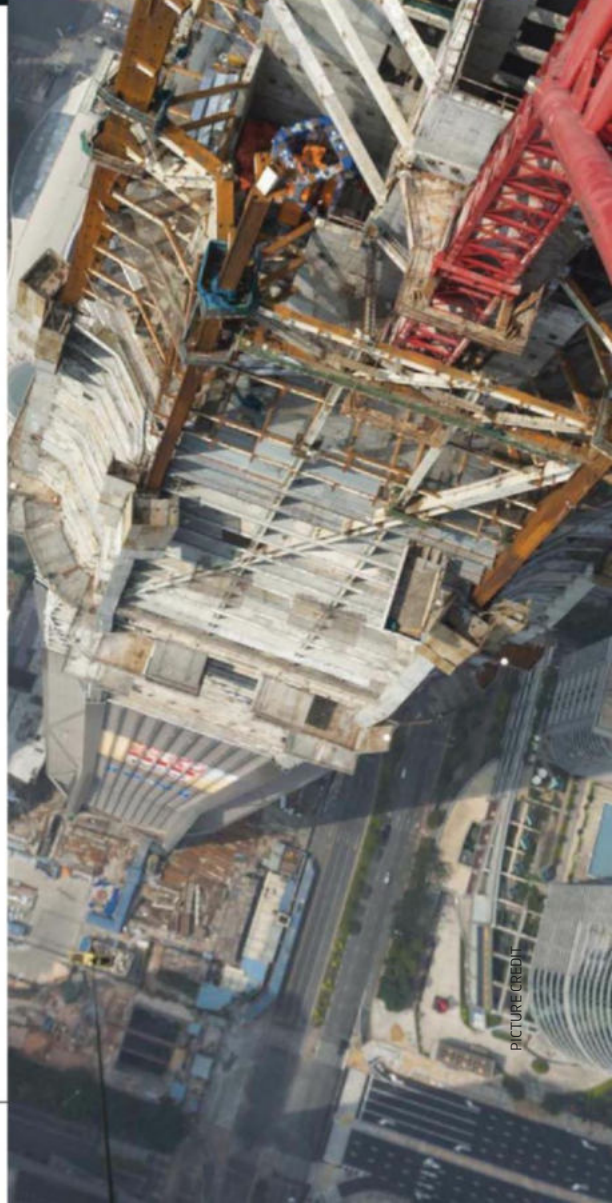
That partly depends on their sex. Research shows that men are more likely to take physical risks to show off strength and daring, especially if they are young and if women are watching. Women have evolved to be more cautious, presumably because of the need to protect their offspring. But women take more social risks than men. People who love excitement and thrills enjoy risky behaviours, and upbringing and environment play a part too. So does peer pressure. We are all more likely to take risks if others around us are doing so, even if we correctly assess the danger. **SB**

The team on the Gemini 11 mission created a weak gravitational force by rotating the capsule

Can we create artificial gravity in space?

CHRIS ROSS-MASSON, MAIDENHEAD

Even before the first space flight, engineers such as Werner von Braun believed the 'centrifuge effect' produced by spinning was the simplest way to create artificial gravity. It was first achieved half a century ago by US astronauts Pete Conrad and Richard Gordon, who succeeded in getting their Gemini 11 capsule to rotate once every seven minutes. This created a weak but detectable gravitational force on the vessel. **RM**

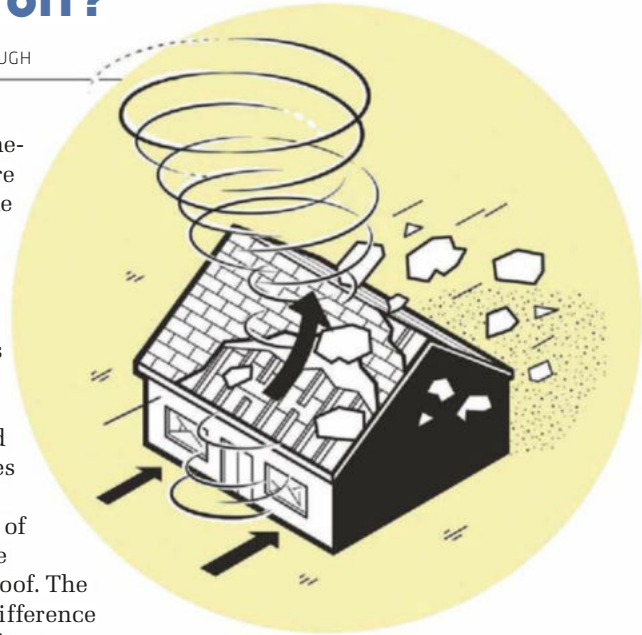




How do tornadoes rip roofs off?

BOB WILCOX, PETERBOROUGH

In the US, around one-third of tornadoes are strong enough to take the roofs off houses. They do this via a double-whammy effect: the fast-moving wind causes a sudden pressure drop over the roof, while debris trapped in the vortex smashes doors and windows, triggering an inrush of air that increases the pressure under the roof. The resulting pressure difference then rips the roof off. **RM**



Can a bad dream cause a heart attack?

CLIVE DANIEL, BY EMAIL

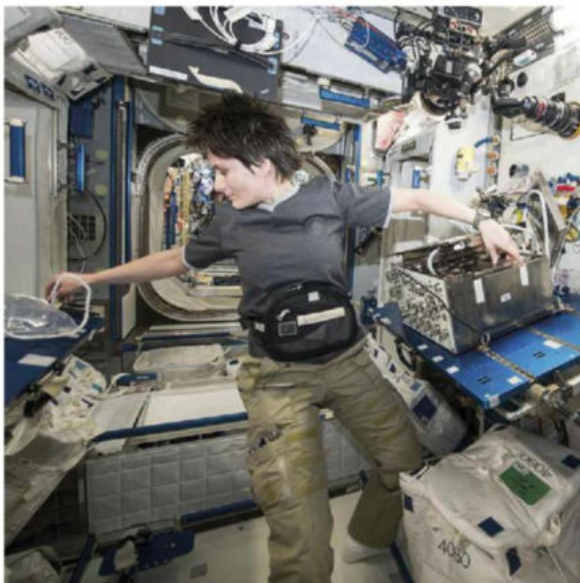
A 2012 study at Case Western Reserve University in Cleveland identified a protein called KLF15 that is involved in regulating the electrical impulses that synchronise your heartbeat. The lowest levels of this protein in the blood occur between 6am and 10am, and this is the most common time of day for the kind of sudden heart attack caused by heart arrhythmia. This is also the time of day when you are most likely to be having vivid dreams, but it's more likely that the stress of the heart attack would give you the nightmare rather than the other way around. **GM**



Is there air conditioning on the ISS?

CAROL MOORE, POOLE

Yes. The ISS is exposed to temperatures of -157°C to 121°C . It either radiates heat in the Earth's shade or warms up in strong sunlight. Like a giant hot water tank, it is lagged with layers of Mylar insulation. Inside, water pipes absorb excess heat from the crew and their equipment. Via a heat exchanger, the water warms up an ammonia-filled radiator on the outside. With its low freezing point, the ammonia stays liquid while releasing heat into space. **GM**

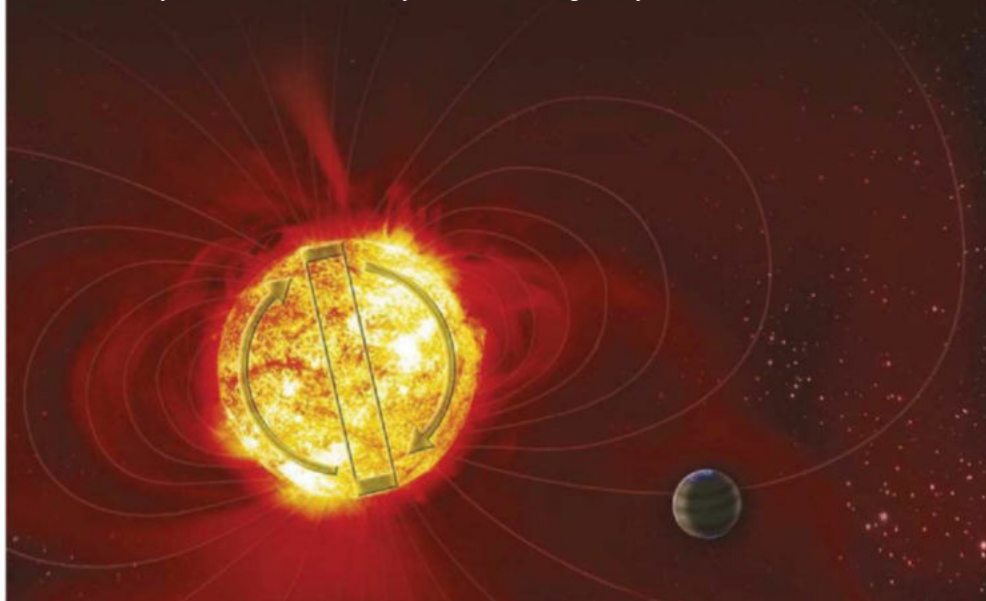


Why are some stars magnetically attracted?

TALLIE BLANSHARD, HONITON

Magnetic fields are created by the motion of electrically conductive material. In some stars, the ionised plasma of their interior undergoes convection. It rises and falls through the outer layers of the star, due to the heating from the stellar core. This, combined with the rotation of the star, creates a 'dynamo' that constantly

regenerates the star's magnetic field. The most magnetic stars are those with faster rotation and deeper convection. Other compact and fast-rotating stars, such as pulsars, magnetars and white dwarfs, retain a significant magnetic field from the original star that is increased dramatically when the object collapses under gravity. **AG**



WHAT CONNECTS...

...BUGS TO STRAWBERRY YOGHURT

1.

Cochineals are 5mm-long scale insects that live on cactus plants in South America, Mexico and Arizona. They produce carminic acid in their bodies to make them unpalatable to other insects.

2.

Cochineals are farmed on prickly pear plants. It takes three months for the insects to reach maturity and then they are brushed off the cacti by hand, before being packed into bags.

3.

The harvested insects are dried and ground up to make cochineal dye. The insects are about 20 per cent carminic acid, yet it still takes 90,000 insects to make a kilogram of dye.

4.

The water-soluble dye is used in cosmetics and as a food colouring. Cochineal gives most strawberry yoghurt its pink colour. Look for cochineal extract, carmine or E120 on the ingredients label.





WHAT IS THIS?

Ogof Fynnon Ddu caves

This cave system is situated in the Brecon Beacons in Wales.

During the Industrial Revolution, a lime kiln was built above the cave. Over the course of 150 years, lime dissolved in rainwater seeped through the cave's roof to form the columns seen here.



IN NUMBERS

10 days

is the amount of time that tardigrades can survive in the vacuum of space

907 kg

of waste is generated by each person in Bahrain every year – the highest amount of any country

TOP 10

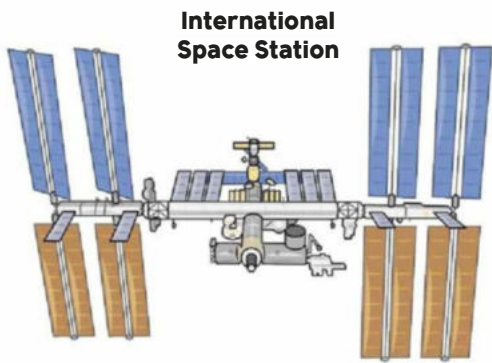
Can a computer be self-aware?

NATHANIEL HEY, ST OVEN, JERSEY

In 2015, New York researchers used three NAO robots to address that question. Each was programmed to believe that two of them had had their voice deactivated. When asked which had been muted, one robot said it could hear itself so therefore must be the only one not silenced. The researchers have fallen short of saying that this robot is self-aware, instead saying it harbours a “logical and a mathematical correlate to self-consciousness”. **GM**

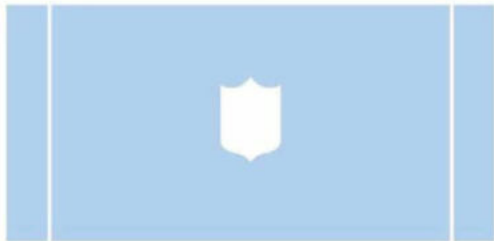


MOST FAMOUS SATELLITES

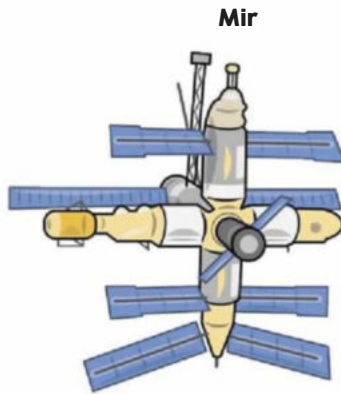


International Space Station

109m



American football field

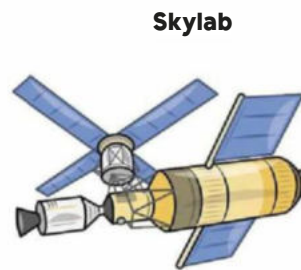


Mir

31m



Blue whale

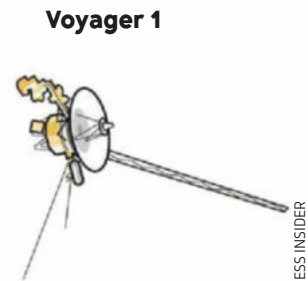


Skylab

26.3m



Brachiosaurus

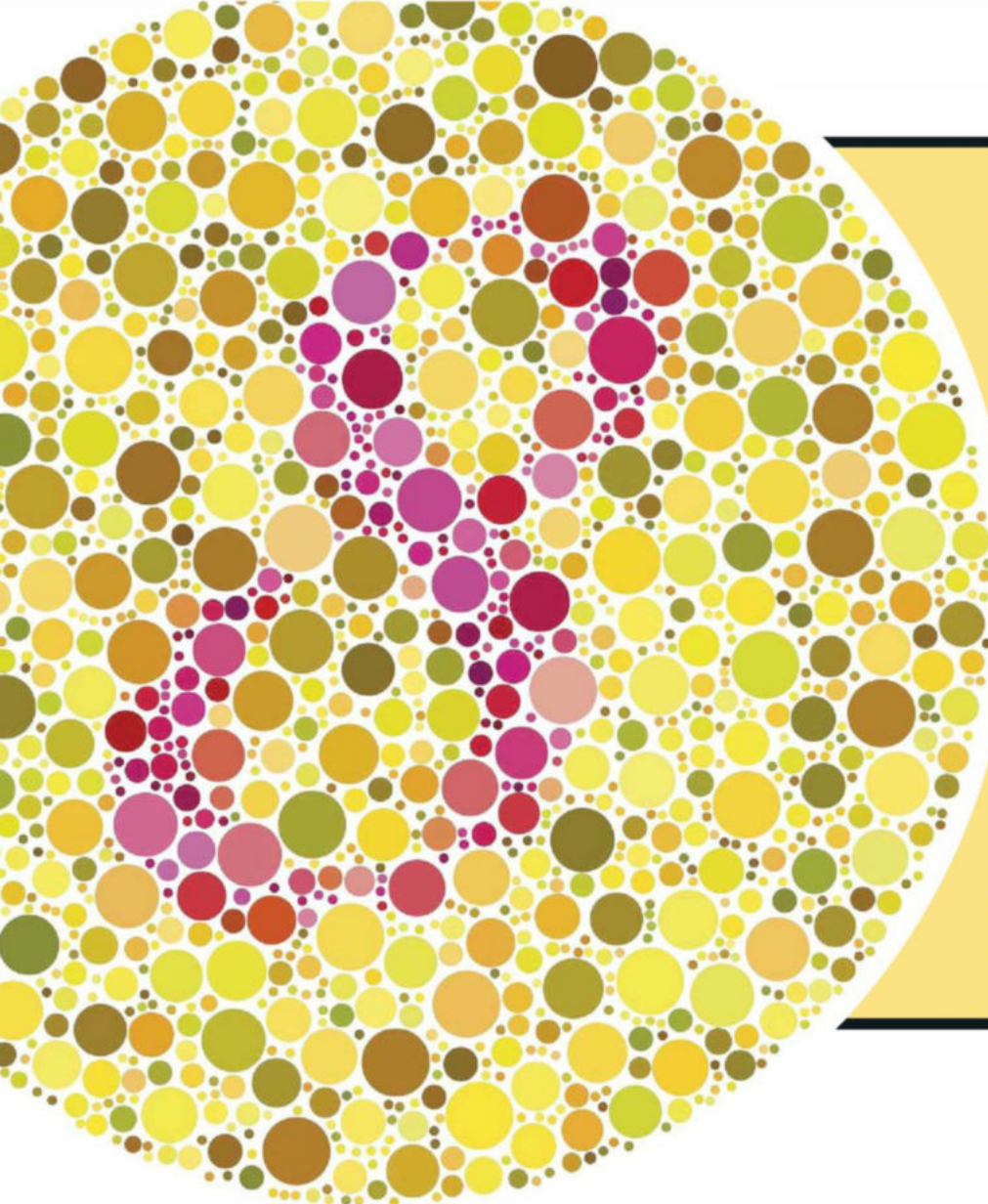


Voyager 1

17.4m



Semi-trailer truck



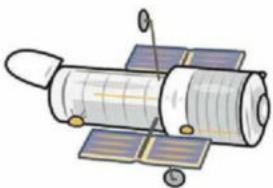
Why do people see the same colours differently?

PAVEL SIZOV, LONDON

Usually because they have more or fewer types of cone cells, the wavelength sensitive photoreceptors in the retina at the back of their eyes. Most people are trichromats, having three types of cone. Dichromats have one of the cone types missing. Men are far more prone to dichromacy than women because the genes involved are on the X chromosome, so the trait is sex-linked. Rarer still are monochromats who have two or even all three of the cone pigments missing. This is known as total colour blindness.

Experiments can easily show which colours someone can distinguish, but it is not so easy to know how the colours look to them. This is especially peculiar when it comes to the rare cases of tetrachromacy. These are people, mostly women, who have an extra set of cones. They can distinguish far more colours than anyone else. But what are those colours, and could the rest of us ever know what their world looks like? **SB**

Hubble Space Telescope



13.3m



School bus

NuSTAR

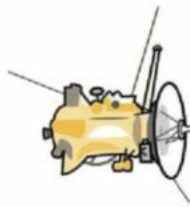


10.9m



1.5 limousines

Cassini Orbiter



6.7m



Kayak

New Horizons



2m



Grand piano

Mar Orbiter Mission



1.5m



Black bear

Sputnik 1



0.6m



Beach ball



Could habitable worlds orbit two stars?

LIAM FARMER, BIRMINGHAM

Whether planets are habitable or not depends on several factors: the radius of the planet's orbit, its atmosphere, its mass and the amount of energy given off by the host star (or stars). If two stars are sufficiently close together (orbiting each other every 10 days or less) their combined heat just resembles that from a single star. In this case, the habitable zone is larger than for a single star. But if the two stars are much further apart, planets will have unstable orbits and will experience extreme variations in temperature, which would probably make them uninhabitable to life. **AG**

Why does glass shatter so violently?

MARY LENHAM, ANDOVER

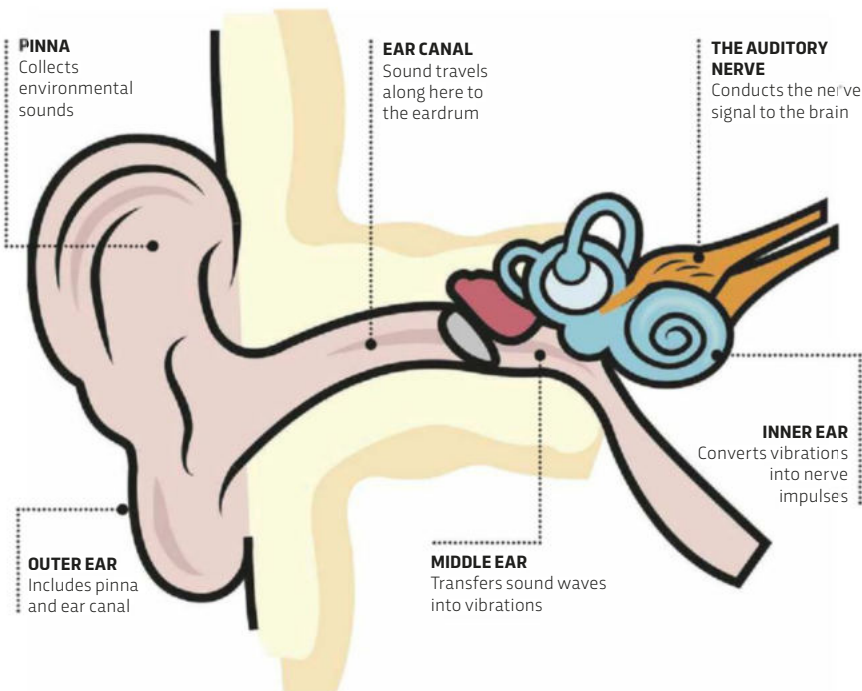
Everyone who's dropped a glass object knows how the fragments sometimes end up astonishing distances from the point of impact. It's as if something was propelling them. And there is an extra source of energy, in addition to the kinetic energy generated by the fall. It comes from the thermal stress left in the glass after it was made.

Glass objects are made from sand, soda ash and limestone heated to 1,700°C. They have to be specially treated – 'annealed' – during manufacture to help release the stress trapped inside; if the glass is cooled too quickly, it can crack before leaving the factory. But dropping it afterwards can release residual stress.

A dramatic demonstration of the effects of improper annealing is provided by the tadpole-shaped glass objects known as 'Prince Rupert's Drops', named after a 17th-Century German aristocrat who gave a set to King Charles II for entertainment. They are created by dripping molten glass into cold water, causing the drops to chill rapidly on the outside, but much less so internally. As the interior cools and contracts, it pulls on the outer surface, creating a huge amount of thermal stress. Snapping the tail of the drops causes cracking that unleashes the pent-up energy, making the drop explode spectacularly. **GM**

Does ear shape affect hearing?

WALT HADDOCK, CALIFORNIA, US



Yes. The outer part of your ear, the pinna, is shaped to amplify sounds and locate their source. Try listening to a steady sound while moving your head or bending your ears. The changes you notice are what the brain uses to determine location, and the pinna's shape exaggerates these variations. Everyone's ears are different, so we learn this skill from infancy. In experiments, people wearing false ears have trouble localising sounds for up to six weeks but they don't lose the ability to hear without them. So this is more like learning a new language than adapting to a new sense. **RM**



PHOTOS: SCIENCE PHOTO LIBRARY, GETTY ILLUSTRATION: PHIL ELLIS

NEXT ISSUE:

Do insects sleep?

Why is water clear?

Can computers learn?





HELEN CZERSKI... WHY IS WIND SO NOISY?

"IT WOULD FEEL WRONG IF WE COULD SEE PEOPLE BEING SHOVED ABOUT BY INVISIBLE FORCES"

Standing on a hilltop on a blustery day feels familiar and comfortingly raw, especially if there's the promise of a decent pub further down the path. But being pummelled by the wind has a side effect, one that we're so used to that we can't imagine gusty days without it. That side effect is the sound – the constant roar that seems to come from all directions. Wind noise can drown out almost everything else, so you have to shout to be heard. But I often find myself pondering where this sound comes from.

One of society's favourite philosophical questions is about whether a falling tree makes a noise if there's no one there to hear it. As a scientist, I would say that it does – a perfect microphone that measured physical reality without getting involved in any way would certainly pick up sound waves. But maybe the philosophers should move on to considering wind noise. As I look out from a hilltop, across a valley covered by a torrent of air rushing through and above the landscape, I can choose a position high in the air, right in the middle of the flow. At my chosen point, the wind speed is even faster than where I am, but I know that it is quiet.

The reason that you and I will always hear wind noise is because the source of it is... you and I. The wind flowing towards us is relatively steady. But our heads, our noses and even the slightly lumpy shape of our ears – these are all obstacles to that flow. As the air meets these obstacles, it's pushed sideways and upwards and a patchy shifting pattern of swirls and pockets forms. Our heads themselves generate turbulence, especially at the sides where our ears are. Instead of flowing steadily, the air swirls are being shoved around, and little pockets of high and low pressure are carried around with them. This means that the pressure at any single point rises and falls as the swirls go past. The sound waves that we hear are just variations in pressure, but our ears can't tell the difference between pressure variations from speech and pressure variations from the air patterns. Just a few centimetres away from our heads, there's little of this complication. But if you put a microphone, a hearing aid or a human into fast-flowing air, turbulence right at the surface is inevitable. And the faster the wind speed




is, the worse the turbulence gets.

None of this stops normal sound from being produced or moving around. The problem is that any other sounds now get lost in the roar of turbulence. It's a particular problem for people who wear hearing aids – anything that sticks out a bit acts as an obstacle, so the wind noise gets even worse. Covers help to eliminate the turbulence a bit – that's why microphones are often covered with sleeves of foam or fluff. But on a properly windy day, you're mostly just stuck with it.

I like the sound of wind, even though it's frustrating to have to shout. It is a weird thought that just a few metres away, there is no roar. But at least the sound adds drama. It would feel wrong if we could see trees and people being shoved about by invisible forces but we heard nothing. So I prefer to think of it as our own ears generating the perfect soundtrack to accompany the dramatic pictures. **F**

Dr Helen Czerski is a physicist and BBC science presenter whose most recent series was *Colour: The Spectrum Of Science*.

DISCOVER MORE

 Did you miss *Colour: The Spectrum Of Science*? You can buy all three episodes of the series in the BBC Store at store.bbc.com

NEXT ISSUE: GERMINATION



STAR ATTRACTION

A red giant star bathes its planets in a fiery glow



UNDERSTAND THE LIFE CYCLE OF A STAR

From clouds of gas to burning beacons and cataclysmic explosions, the life of a star is both violent and restless

WORDS: BRIAN CLEGG

What exactly is a star?

It's a massive ball of plasma, the fourth state of matter on top of the familiar solid, liquid and gas. A plasma like that in a star is the result of heating a gas so much that its atoms lose electrons, producing a mix of positively charged 'ions' and free electrons. The sheer amount of matter in a star is phenomenal. The Sun, for instance – our neighbourhood star – contains over 99 per cent of the mass of the Solar System. And it's more than 300,000 times the mass of Earth.

How are stars born?

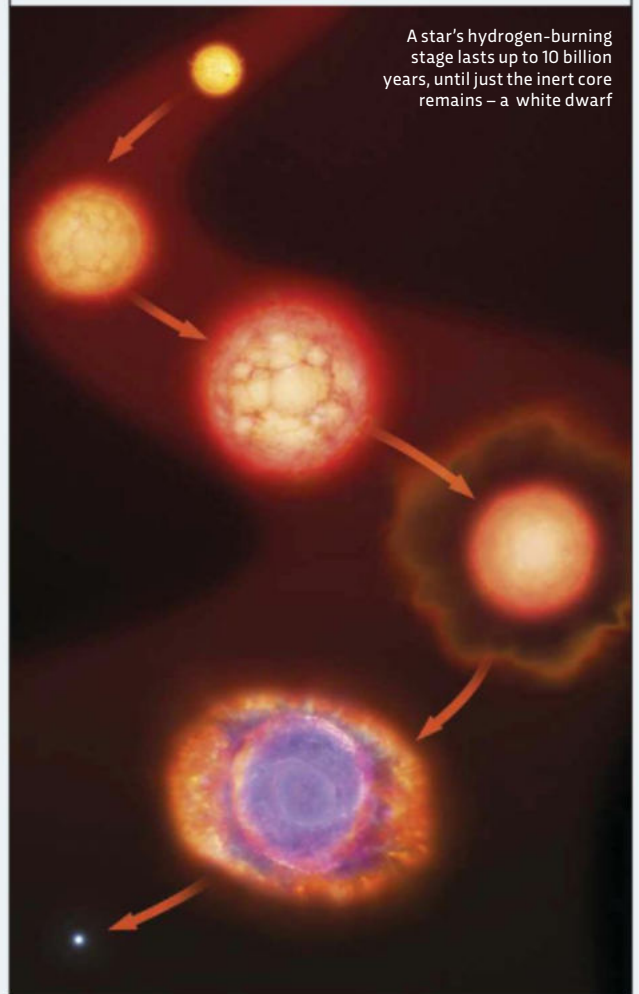
Looking into the night sky, it might seem that most of space is empty, but the gaps between the stars contain molecules of gas, the majority of which are the lightest element: hydrogen. These molecules can drift around indefinitely, but some areas have a greater amount of gas than others. Where these 'molecular clouds' are particularly dense, there can be enough gravitational attraction to pull the gas molecules together in a clump.

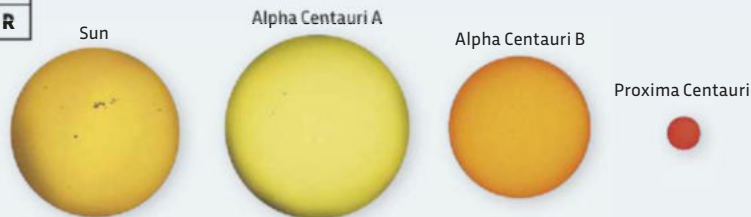
This can happen as a result of random motion, but is sometimes triggered by nearby events. One example is the shock wave from the explosion that sometimes occurs as the final gasp of a star, which can push molecules together so that the death of one star seeds the birth of another.

As the gas molecules are crammed together tighter and tighter by gravity, they heat up, in the way that a bicycle pump gets warm when you compress the air in it. But in the star, the scale of this compression is so great that it can transform a dense ball of plasma into a nuclear reactor emitting vast quantities of energy.

Where does the star's power come from?

As the gas that formed the star gradually comes together, it gets hot enough to form a plasma, which starts to glow, albeit very faintly compared with the vast energy output of a star. As the material continues to condense – a process that will take hundreds of thousands of years – the temperature and





➔ pressure get higher and higher. In the heart of a star like the Sun, the temperature can easily reach 10,000,000°C. Under these conditions, a process called nuclear fusion can take place.

In fusion, light elements are combined to form heavier ones. The typical star reaction builds a more complex nucleus from hydrogen nuclei (the ions left when an electron is stripped off a hydrogen atom), forming the next heaviest element: helium. When the ions get very close together, a force that pulls them towards each other – called the strong force – overwhelms the electrical repulsion between their positive charges.

However, even in the heat and pressure of the core of a star, the ions aren't squashed close enough for the very short range strong force to take hold. The star also relies on a weird quantum effect called tunnelling, which means that quantum particles like ions can pass through a repulsive barrier as if it were not there, getting the ions close enough to fuse. This process produces a flow of energy in a nuclear fusion reaction – the same source of energy used to devastating effect in the hydrogen bomb.

Some of this energy is given off as heat, and some as light, so photons of light start to find their way out of the vast ball of the star. But it's very easy for the photons to be absorbed by another part of the plasma, then re-emitted later – so in practice it can take millions of years for light emitted near the heart of a star to emerge. The energy output of a star is vast. The Sun, for instance, puts out around 400 billion billion megawatts, of which around 89 billion megawatts hits the Earth. Though only a minute fraction of the solar output, this figure is

thousands of times the energy that humans currently use.

Is the Sun a typical star?

The Sun looks very different to the tiny points of light that stars appear to be, but that's just a matter of distance. The nearest star after the Sun, Proxima Centauri, is around 250,000 times further away. Although at first sight all the stars visible with the naked eye look pretty much the same, there are variations in colour and brightness. In the confusing terminology of astronomers, the Sun is a yellow dwarf star. Confusing because it's not yellow, and it's not particularly small. The Sun is actually white – it just appears yellow because the bluer parts of its light are scattered by the atmosphere, producing our blue sky. And the term 'dwarf' is used to contrast stars like the Sun with huge stars, known as giants. In reality, the Sun is in the top 10 per cent of stars in the Milky Way for brightness.

Like the majority of stars, the Sun is what is called a main sequence star. This refers to a curve in the middle of a diagram showing different types of stars known as the Hertzsprung-Russell diagram (see opposite page). Stars on the main sequence are all dwarfs, ranging in colour from blue to yellow. They are given a letter to indicate their position on the sequence, which confusingly run in the order O B A F G K M as they go from the hottest O stars to the coolest M stars. The Sun is a G-class star, near the middle of the range.

What will happen when the Sun runs out of hydrogen?

As a star like the Sun converts its hydrogen into helium, it becomes hotter. This is because the helium takes up ➔

↓ The Crab Nebula, caused by a supernova nearly 1,000 years ago



JARGON BUSTER

Core

The heart of a star. With an extremely high temperature and pressure, this is where most nuclear fusion occurs.



Ion

An atom that has lost (or gained) electrons so that it is electrically charged. Stars are made up of ions



Nebula

A fuzzy object in the sky, from the Latin for 'cloud'. The word was originally used for anything spread out, including galaxies, but now only for a cloud of gas or dust.



Quantum tunnelling

The particles that make up matter and light behave very differently to familiar objects. Such particles do not have a specific location, making it possible for them to appear on the other side of a barrier without passing through it.

This is quantum tunnelling



Standard candle

Stars or supernovas with a known brightness are often used to measure distances in space, as the further away they are, the dimmer they will seem

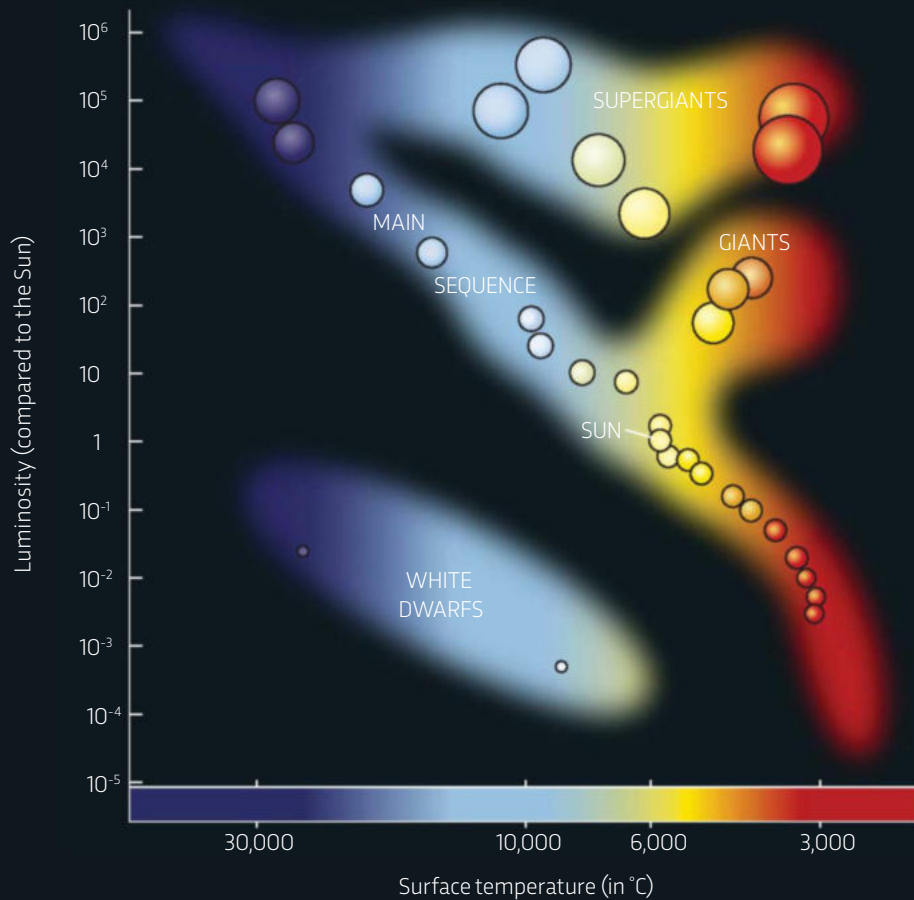


Strong force

One of the four fundamental forces of nature, the strong force is responsible for the attraction between nuclear particles. The strong force is extremely short range – particles have to get very close to each other before it has a noticeable effect.

PLOTTING THE LIFE CYCLE OF A STAR

THE HERTZSPRING-RUSSELL DIAGRAM



When astronomers compared the brightness of stars to their surface temperature, measured by colour, the stars fell into clear groups on a chart that became known as the Hertzsprung-Russell diagram, after its main contributors Ejnar Hertzsprung and Henry Russell.

Many stars, like the Sun, lie on a curve running diagonally across the centre of the diagram – the main sequence. Giants and supergiants sit off the main sequence to the top-right, while dim, white or blue stars occupy a space in the bottom-left. The diagram is a graphic illustration of the life cycle of stars, with most stars spending time on the main sequence as they perform hydrogen fusion, heading towards the top-left as they increase in temperature.

After some initial confusion, when it was assumed that stars always got smaller over time, it was realised that both 'islands' above and below the main sequence were stars that had left the sequence as they evolved.

WHAT WE STILL DON'T KNOW

1 WHAT CONDITIONS MADE STAR FORMATION POSSIBLE?

Initially, the Universe was too energetic for stars to form. But as it expanded and cooled, it became possible for gravity to form clumps of gas. There is a suggestion from the European Planck satellite that conditions made it possible for stars to form within 500,000 years of the Big Bang, but space telescopes and cosmic microwave background detectors will confirm more about the early Universe.

2 THE MECHANICS OF SUPERNOVAS

Although there are theories on how supernovas work, there's not enough evidence that these theories are correct. For example, neutron stars often leave a supernova explosion at high speed, but nobody knows why the explosion favours one direction only. Some of the most useful supernova observations come from X-ray and gamma ray space telescopes like Chandra and NuSTAR, which constantly add data that may help us understand these massive stellar explosions.

3 ARE THERE POPULATION III STARS?

Stars are classified either as Population I (metal-rich) or Population II (metal-poor). The older Population II stars contain fewer heavy elements than the younger Population I stars, which were formed from gas enriched with heavy elements from supernovas. However, cosmological models suggest that there should also be huge, ancient Population III stars, made almost entirely from hydrogen and helium, and created soon after the Big Bang. These are yet to be detected, but the James Webb Space Telescope – launching in 2018 – could change that.



Mirrors for the James Webb Space Telescope undergo tests



In one tweet...

Stars don't stay the same: they evolve, getting hotter before fluffing up and either shedding an outer layer or exploding as a supernova.

➔ less room, allowing the core of the Sun to contract and generate more heat. This moves the star up the main sequence. The Sun has been in existence for around 4.5 billion years, during which its brightness has already increased by about 30 per cent, and it will spend 10 billion years on the main sequence altogether. We probably have another two to three billion years before the Sun gets so hot that the Earth becomes uninhabitable.

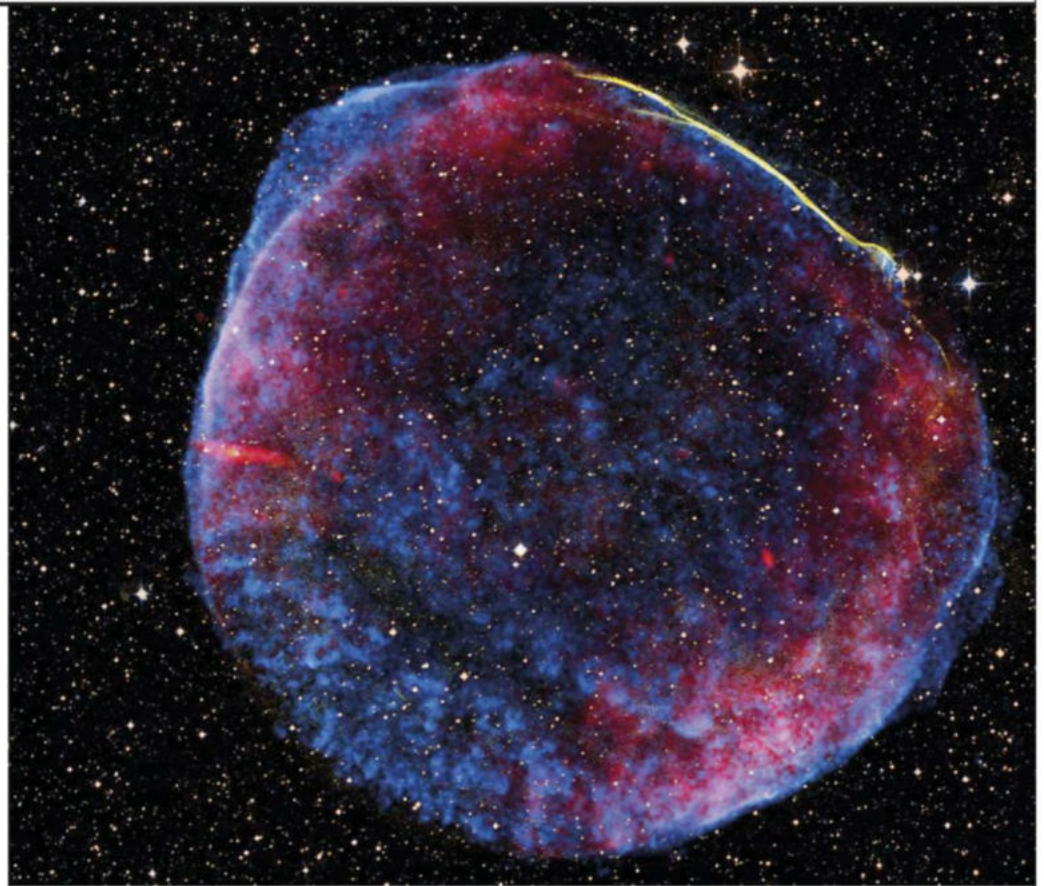
When the vast majority of the hydrogen in the core has been used up, a star can no longer stay on the main sequence. Like similar stars, the Sun is expected to become a red giant (typically an orange colour), ending up perhaps 200 times bigger than it is now.

This process happens because the core, lacking hydrogen reactions to fluff it up, collapses, generating a lot of energy which pushes away the outer parts of the star. The star is still powered by hydrogen fusion, but this is now spread over a wider shell, reducing the star's surface temperature and producing its redder colour. The Sun is expected to remain a red giant for somewhere in the region of a billion years.

And then what?

When most of the hydrogen is exhausted, the Sun will reach a point where helium fusion can take place. In a rapid process known as a helium flash, around one-tenth of its helium will be converted into carbon. (Although it's called a flash because there will be a huge energy release, it won't be visible, as the light will not get out of the Sun.)

For the next 100 million years or so, the Sun will burn through the rest of its helium, followed by a series of pulses as the core



A composite image of the SN 1006 supernova remnant

collapses again, leading to a point where it has entirely blown off most of its outer layers. Those layers form a glowing cloud of gas called a planetary nebula around the remainder of the star. It should be no surprise by now that this name is misleading – when first observed around other stars, such clouds were thought to be caused by planets.

The core of the Sun that remains will be much hotter than its earlier surface, forming a miniature white star – perhaps similar in size to the Earth – at the centre of the nebula, called a white dwarf. By this stage, there is no more fusion occurring, so the star gradually fades over billions of years. It's expected eventually to become a black dwarf, giving off hardly any light, but none of these exist yet because the Universe has not

been here long enough for them to form.

What happens to stars that are bigger than the Sun?

The very bright O main sequence stars and the most massive B stars take a different path to the Sun as they evolve. These stars, typically 10 or more times the mass of the Sun, have extremely short lives, ranging from hundreds of thousands to tens of millions of years. Because of their extra gravitational pull, they burn through their core hydrogen quicker and expand to form red supergiant stars. In these, helium begins to fuse as soon as the core hydrogen is depleted, followed by further fusion reactions. These produce not only carbon but also the heavier elements all the way up to iron, which is the end of the road for

1 A STAR IS BORN

Stars are formed when clouds of gas are pulled together by gravity. As the gas particles are squeezed closer and closer together, they warm up. Eventually they are pressed together so closely that they begin to join up, giving off energy in nuclear fusion: the cloud has become a star.

2 STARS ARE RESTLESS OBJECTS

Stars are restless objects. Not all stars are the same: they differ in size, brightness and colour. What's more, they evolve over time. Most stars will get brighter as they move through their life cycle, until they run out of fuel in their core, at which point many of them fluff up to produce a huge 'giant' star.

3 EVERYTHING MUST END

The giant phase does not last forever. A mid-sized star that became a giant is likely to blow off its outer layer as a cloud of gas, leaving a small white dwarf behind. Larger supergiants undergo cataclysmic explosions called supernovas, generating heavy elements and leaving a neutron star or black hole.

A white dwarf accumulating rocky matter

fusion produced by gravity. When the iron core collapses, the outcome is a massive explosion – a supernova.

Can we detect supernovas on Earth?

Supernovas produce immense bursts of light. This means that a star that's usually much too far away to be seen suddenly becomes visible. What seems to be a new star appears in the sky – these were originally named 'nova' as a contraction of 'stella nova', the Latin for 'new star'. (The naming system later changed, making a nova a special kind of star explosion where a white dwarf sucks in material from a nearby star, so the original nova was renamed a supernova.) Supernovas can be so bright that they are briefly visible in the daytime. As the supernova subsides, the result is a vast swirl of stellar debris called a nebula. The best known of these is the Crab Nebula, the remainder of a supernova seen on Earth in 1054 and recorded by Chinese astronomers. With modern telescopes, we can detect supernovas in galaxies outside the Milky Way, and because particular types of supernova have similar brightness, they are used as 'standard candles' to measure the distance to galaxies.

What happens after a supernova?

During a supernova, the outer parts of the star are blasted off by a pressure wave so intense that atoms heavier than iron, such as copper and gold, can be formed. The inner remnant of the star continues to collapse, and depending on its size will form either a neutron star – an immensely dense star composed solely of neutron particles – or a black hole, where the collapse has become unstoppable and the



← The constellation of Taurus

star ends up as a dimensionless point with a gravitational pull so strong that not even light cannot escape.


Can we see all the different stages of star in the night sky?

Most star types can be observed, with the exception of black dwarfs. Dwarfs are by far the most common stars in the Milky Way, but there are also red giants, like Aldebaran, located in the constellation of Taurus, and supergiants, such as Rigel, the bottom-right star in the constellation of Orion.

Neutron stars and black holes can't be seen directly, but we can observe their effects. Neutron stars, for instance, usually rotate rapidly and give off lighthouse-like beams, which we see as flashing sources known as pulsars. And the existence of black holes can be deduced from their impact on matter around them, which gives off radiation as it plunges towards the collapsed star. Most difficult to spot are brown dwarfs, which fall between a gas giant planet like Jupiter and a star. They aren't massive enough for hydrogen fusion to be triggered, so they glow faintly as a result of the heating caused by contraction – essentially, they're failed stars. **F**

Brian Clegg is a prolific science writer with a background in physics. His most recent book is *Ten Billion Tomorrows* (£13.99, St Martin's Press).

DISCOVER MORE

 The *Wonders Of The Universe* series, presented by Brian Cox, is available now in the BBC Store at store.bbc.com

 Listen to Melvyn Bragg and guests discuss the life of stars in an episode of BBC Radio 4's *In Our Time* bbc.in/Mm0o82

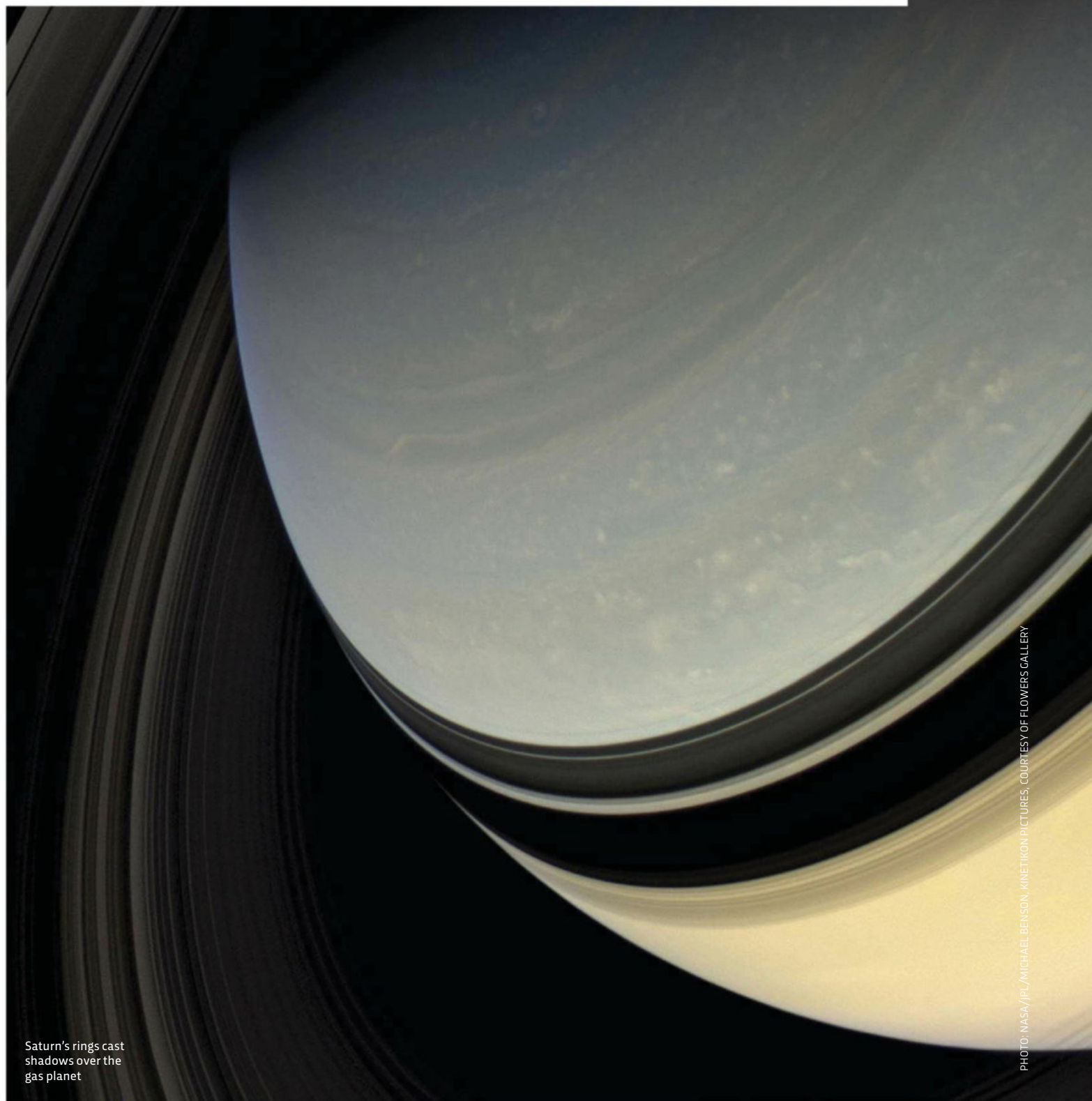
NEXT MONTH: HOW DO WE KNOW HOW TO FORECAST THE WEATHER?

OUT THERE

WHAT WE CAN'T WAIT TO DO THIS MONTH

FEBRUARY 2016

EDITED BY JAMES LLOYD



Saturn's rings cast shadows over the gas planet

PHOTO: NASA/JPL/MICHAEL BENSON, KINETRON PICTURES, COURTESY OF FLOWERS GALLERY



01 TOUR LONDON'S LATEST SHOWS

OTHERWORLDS: VISIONS OF OUR SOLAR SYSTEM

NATURAL HISTORY
MUSEUM, LONDON,
22 JANUARY –
15 MAY 2016, £9.90

i See our Solar System in eye-popping detail with a new exhibition at London's Natural History Museum. Artist and writer Michael Benson has painstakingly processed raw data from NASA and ESA to produce 77 stunning images of our neighbourhood, such as this glorious view of Saturn's northern hemisphere and rings. The exhibition features original music by king of ambience Brian Eno, and there's also a free audio commentary offering an extra perspective from some of the museum's leading scientists.





Gertrude hated it when Rupert refused to cut his fingernails

**STATES OF MIND:
TRACING THE
EDGES OF
CONSCIOUSNESS**

WELLCOME
COLLECTION, LONDON,
4 FEBRUARY –
16 OCTOBER 2016, FREE

ii Also opening in London this month is a new show at the Wellcome Collection exploring the strange and ineffable topic of human consciousness. The exhibition uses objects, artworks and films to delve into phenomena including sleepwalking, anaesthesia, memory loss, synaesthesia and language development, promising to reveal “both the wonder and fragility of our internal lives”.



**LEONARDO
DA VINCI:
THE MECHANICS
OF GENIUS**

SCIENCE MUSEUM,
LONDON,
10 FEBRUARY –
4 SEPTEMBER 2016, £10

iii Painter of the *Mona Lisa*, inventor extraordinaire, expert anatomist: Leonardo da Vinci had a pretty impressive CV. If any more proof were needed of his genius, a new exhibition at London’s Science Museum showcases Leonardo’s flair for design and engineering, featuring 40 models based on his intricate drawings, including flying machines, diving apparatus and a prototype tank.



According to Charles Foster, worms taste “mushroom-y” – we’ll take his word for it

PHOTOS: WELLCOME TRUST, SCIENCE MUSEUM, LONDON

02

MEET THE MAN WHO BECAME A BADGER

As well as being a barrister, veterinarian and traveller, CHARLES FOSTER has also spent parts of his life as a badger, an otter and a fox. He tells JAMES LLOYD about his new book, *Being A Beast*

In your book, you set out to experience what it's like to be an animal. What was your thinking behind the project?

As a child, I used to look out at the animals that inhabited our suburban garden in Sheffield, and I wondered, as I looked at them, what they thought of me. For as long as I can remember, I've had this idea that in every other organism, there's a completely different world from the one I occupy. I wanted to explore all these other universes.

The longest chapter in the book is about your experiences of living as a badger for six weeks. Did you really live in a sett?

Yes. My son Tom and I used my friend's JCB to dig out a sett in the Black Mountains in mid-Wales, living there for a while and crawling around on all-fours. At the time, Tom was eight coming on nine. He's much closer to being a badger than I am – his eye level is much nearer a badger's and his brain is much more plastic – so I followed Tom really: he was a great badger tutor.

What was a typical day in your life as a badger?

We tried to adopt the badger's timetable, so we slept mostly underground during the day. At sundown, we'd crawl out of our sett and go travelling around the woods. The badger's landscape is

primarily olfactory, so we'd sniff along the ground and try to follow the shapes of the land made by the rising and falling tides of scent within the wood.

What did you eat?

We ate earthworms, slugs and things scraped off the road, but we also cheated. My mate from the nearby farm would bring us stuff occasionally. It would have been inauthentic to say no – no self-respecting badger would turn its nose up at fish pie!

What do earthworms taste like?

They vary according to the season and the land they come from. People talk about wine having a distinctive *terroir*, and so do earthworms. When the weather's been wet and warm, the worms are at their least charismatic – anaemic and tasteless. Their taste becomes concentrated – like grapes do – when it's been hot and dry. The worms in the Black Mountains were sort of mushroom-y.

What other animals did you experience for your book?

I was an urban fox, rifling through the dustbins of East London; a red deer, looking at whether it's possible for a natural predator like me to

become the predated; an otter in the rivers of Exmoor; and a swift. The swift chapter is probably the most poetic, simply because their world is the most difficult to enter – I can't make myself weightless.

How did you attempt to get inside these animals' heads?

I read everything I could about the way the sensory receptors of these species worked, and what's known about the central processing [in the central nervous system]. Only after I completed this exercise did I go into the woods or the river. It's so easy when you're writing about animals to be anthropomorphic – to assume that we can intuit things about the way they work. Intuition can get you somewhere, but it's hugely more valuable if it's scientifically informed.

What's the most important thing you've learnt from your experiences?

Non-human species are a lot closer to us than we think. Their worlds are not completely inaccessible, and that opens up the possibility of an amazing world of relationships. I'm now an even more passionate conservationist than I used to be. We *can* have real relationships with other species.

BEING A BEAST BY CHARLES FOSTER

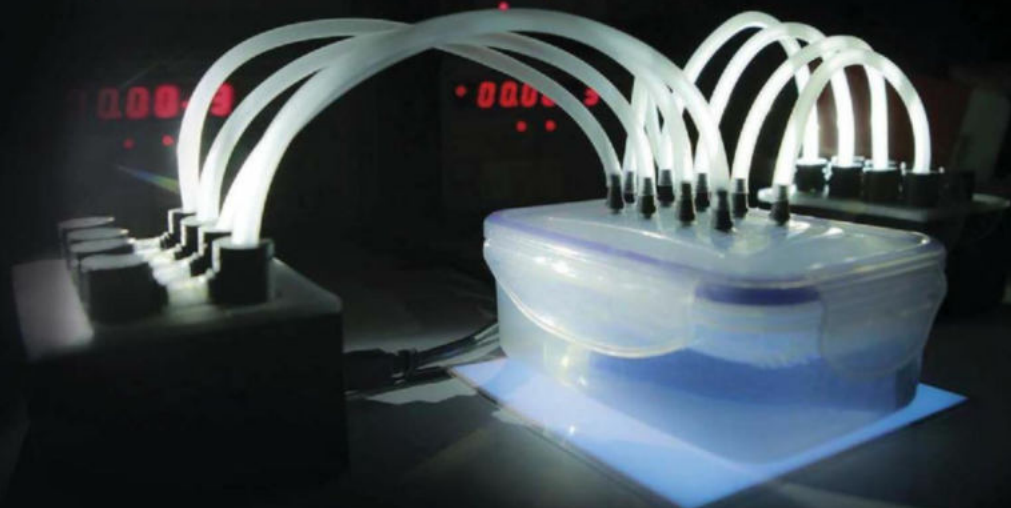
IS PUBLISHED ON 4 FEBRUARY (£14.99, PROFILE BOOKS).



03 SEE A SLIME MOULD PLAY THE PIANO

PENINSULA ARTS CONTEMPORARY MUSIC FESTIVAL

PLYMOUTH UNIVERSITY,
26-28 FEBRUARY
2016, MOST EVENTS
ARE FREE



If you're into science and music, Plymouth is the place to be this February. Now in its 11th year, the Peninsula Arts Contemporary Music Festival showcases genre-defying music that's inspired by the latest scientific research.

One of the highlights promises to be Eduardo Reck Miranda's *Biocomputer Rhythms* in which a slime mould – an otherworldly creature that's neither plant nor animal – plays the piano. By hooking the slime mould up to a circuit board, Miranda has created a biocomputer that listens and responds to sounds in real

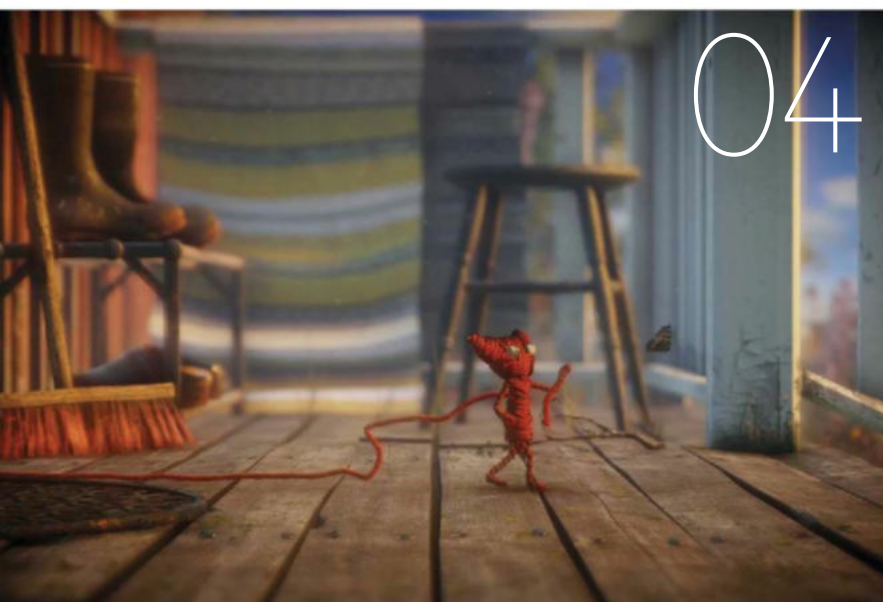
time, generating its own music via electromagnets attached to the piano strings and various percussion instruments.

Other events at this year's festival include *Sonification of Dark Matter*, which creates sounds from data produced in a dark matter simulation; a talk introducing some of the latest tech being developed at Plymouth University, allowing someone to make music using only their brain's electrical signals; and a composition inspired by Darth Vader, Luke Skywalker, Superman and Batman.

DON'T MISS

THE SKY AT NIGHT

This month's episode looks at the five best photos taken by the probes we've sent through the Solar System. Watch it on BBC Four, Sunday 14 February at 10pm.



04

HANG OUT WITH YARNY, THE STAR OF UNRAVEL

One of our most anticipated video games of 2016 has an unlikely hero: a small, anthropomorphic ball of yarn. In *Unravel*, you take control of Yarny, using his single red thread to solve physics-based puzzles as you adventure through the game. With a heart-rending storyline and gorgeous visuals inspired by the countryside of northern Scandinavia, we can't wait to get our hands on this one.

UNRAVEL IS RELEASED ON 9 FEBRUARY ON PC/PS4/XBOX ONE (£14.99, ELECTRONIC ARTS).

PHOTOS: LLOYD RUSSELL, ELECTRONIC ARTS

05 GET TO KNOW YOUR FLAWED BRAIN

THE IDIOT BRAIN

IS PUBLISHED ON
18 FEBRUARY
(£12.99, GUARDIAN
FABER).

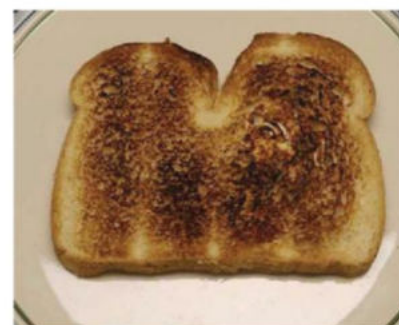
The human brain is a marvellous organ, the most complex single thing known to mankind. But, as neuroscientist DEAN BURNETT reveals in his new book *The Idiot Brain*, it messes up with surprising regularity. Here, he reveals five things your brain gets wrong...

1 IT DOESN'T KNOW HOW MUCH YOU'VE EATEN

Although our digestive systems have complex networks of nerves and hormones to monitor our food intake, the brain can, and regularly does, overrule this. If your brain doesn't remember eating (which happens with memory disorders) or maybe just sees something it wants that it knows is tasty, it can decide it wants it, stomach and physics be damned!

2 IT SEES FACES EVERYWHERE

From simple arrangements of punctuation to patterns in toast, people see faces everywhere. There *aren't* any faces there though. So why do we see them? It's because the brain has many areas of the visual cortex dedicated to processing different things, one of which is faces. Any image that triggers this bit is perceived as a face, often for no reason.



The Father, the Son and the, uh, Holy Toast

3 IT MESSES WITH YOUR MEMORIES

You might think (or hope) that your memories are a reliable record of information and events. Sadly, they often aren't. The brain regularly modifies recollections for numerous reasons, many of which are ego-based. So people may genuinely remember catching a fish that was "this big".

4 IT'S GENUINELY SCARED OF HARMLESS SITUATIONS

The brain's fear response system is ancient, and very reliable. However, it often can't tell the difference between genuine danger and 'imagined' danger. Singing karaoke, asking someone out, giving a presentation: none of these present any physical danger, but they could lead to social rejection or embarrassment. These feelings are unpleasant, so the brain ends up fearing them as much as it would a furious bear.



5 IT ALWAYS THINKS YOU HAVE MORE TIME TO GET THINGS DONE

Do you know someone who's always late, no matter how much time they have to get ready? It's not surprising: for some reason, the human brain seems to struggle with planning, as it constantly reverts to a more optimistic assessment of available time and work required, no matter how often it's been proved wrong. This is known as the planning fallacy.



MATHEMATICIAN **CÉDRIC VILLANI** SHARES HIS FAVOURITE HAUNTS IN **LYON**



1 MARCHÉ DE LA CROIX-ROUSSE

One of Lyon's two main outdoor food markets. Boulevard de la Croix Rousse, 6am-1pm, Tues-Sun

2 BOUCHON DE L'OPÉRA

A classic Lyonnaise restaurant. 11 Rue des Capucins bouchondelopera.com

3 NINKASI GERLAND

A trendy venue that hosts gigs and concerts. 267 Rue Marcel Mérieux ninkasi.fr/en/locations/gerland.html

4 HÔTEL DE VILLE DE LYON

Lyon's impressive town hall. 1 Place de la Comédie lyon.fr/lieu/services-publics/hotel-de-ville-de-lyon

5 FRESQUE DES LYONNAIS

A famous fresco that features some of the city's most iconic faces. Rue de la Martinière au Quai de la Pêcherie

6 ÉCOLE NORMALE SUPÉRIEURE DE LYON

This university features some interesting architecture. ens-lyon.eu

Lyon is *incroyable*! The city combines culture, beautiful architecture and a fantastic quality of life – plus it's close to the countryside. Every December, I love watching the Festival of Lights, where historic buildings become backdrops for *son et lumière* shows of animations projected onto the facades. It's the perfect way to discover Lyon.

But it's not just beautiful in the winter. I love wandering the streets of Lyon at any time of year, eating at one of the city's great restaurants and food shopping at places like **MARCHÉ DE LA CROIX-ROUSSE** 1. Clothes shopping in Lyon is also good, but I buy my cravats in Paris.

My favourite place to eat in Lyon is the restaurant **BOUCHON DE L'OPÉRA** 2, in which I filmed scenes for the *Colours Of Mathematics* documentary I presented. If you go there, try some of the delicious traditional dishes, such as local sausages, duck pâté or roast pork.

For a snack while I work, or if I simply want to relax, I go to Boulangerie des Chartreux, which has the best crispy baguettes and gorgeous pastries. In the evenings, however, I love to hang

out at **NINKASI GERLAND** 3. This venue serves some great home-brewed beers and hosts lots of gigs.

I love passing by the town hall, the 17th-Century **HÔTEL DE VILLE DE LYON** 4 which mathematician/engineer Girard Desargues helped design, and crossing the Saône river on the stunning Passerelle Saint-Vincent pedestrian bridge.

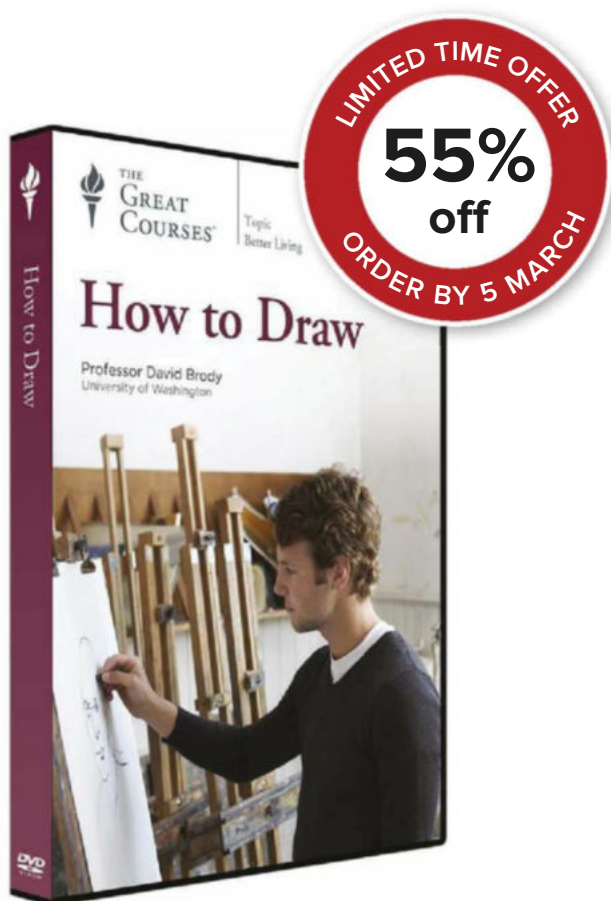
Right next to the bridge is the famous **FRESQUE DES LYONNAIS** 5. Painted on the facade of an old building, this stunning fresco features some of Lyon's most famous people, including scientists and engineers, such as 19th-Century physiologist Claude Bernard, known for defining the term 'homeostasis' and for being the first person to carry out 'blind' experiments [to ensure objectivity]. The fresco also features Auguste and Louis Lumière, the first film-makers in history. The brothers' former home, now the Musée Lumière, is also well worth a visit.

Finally, one of my favourite buildings in the entire city is the boat-shaped **ÉCOLE NORMALE SUPÉRIEURE DE LYON** 6 in the south of the city. But I'm biased because it's where my career really got started when I gained my professor position. 7

Cédric Villani is a French mathematician. He was awarded the Fields Medal in 2010.



ILLUSTRATION: TOWEN JONES



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PHYSICS

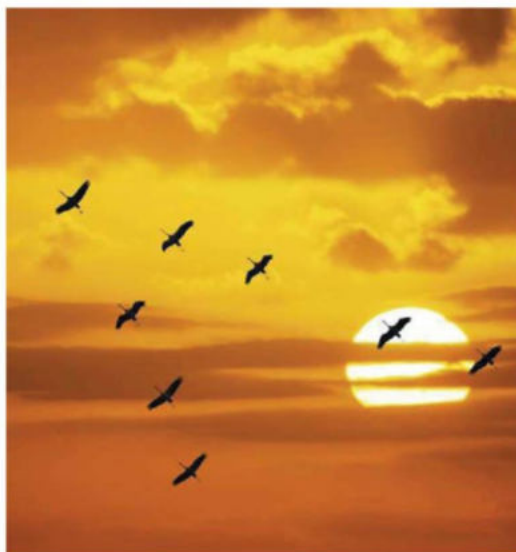
Is the future nuclear?

Five years on from Fukushima, we look at the current state of nuclear power. Can it still play a role in a safer and greener future?

NATURE

THE INSIDE TRACK

Discover the cutting-edge technology that's revealing previously hidden habits and animal behaviours in the natural world.



TECHNOLOGY

DRIVERLESS CARS

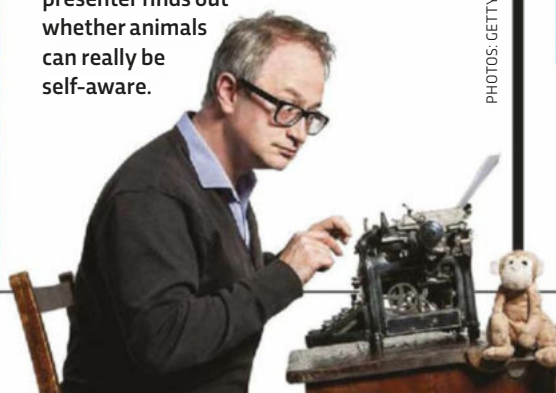
They'll soon be on our roads, but how will they deal with life or death decisions: could your autonomous vehicle decide to let you die?



ROBIN INCE

MONKEY SELFIES

The comedian and Radio 4 presenter finds out whether animals can really be self-aware.



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Feed your mind



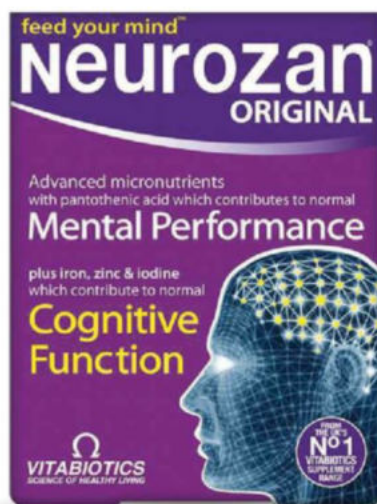
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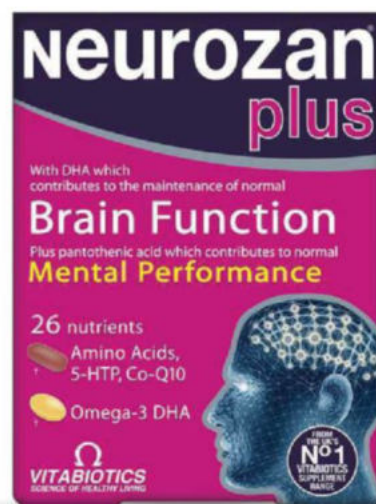
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www.thednastore.com/dnastuff/cufflinks.html



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A few months ago, we wrote about the best ways in which drones are currently being utilised – this includes herding sheep, delivering pizza and even playing cupid, used by some restaurants to dangle mistletoe between loved-up diners on valentines day. That's the best thing about the DJI family – there is a model for everyone; whether you're a photographer, a sheep farmer or simply just want a new toy.


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This beautifully made small sports car AS4 is a homage to the first Mercedes vehicle. It is powered by a Stirling Engine with its fuel source being a small alcohol burner. Made of 100 parts. Ready to run.



These miniature 3cc V-Twin combustion engines run off butane or propane gas. They are small enough to run on your desk and have an awesome v-twin sound. Just turn the valve and flick the flywheel to get it started.



This Vulcan stove fan is driven using Stirling engine technology using just the heat from a stove. It requires no external power source such as batteries or AC power. The fan circulates the stove's warmth quietly, efficiently and inexpensively.



Newly invented, this tractor beam magnet contains a number of magnets in a special arrangement. The special arrangement creates a unique magnetic field that can hold another magnet a fixed distance away.



This is a Hero Steam turbine. Syringe in some water. Fill the burner with methylated spirits and light it. Moments later you have a steam turbine running. Two tiny jets of steam coming out of the side of the brass ball spins it up to 2500rpm.



These are highly polished solid metal flip over tops. They have a chrome like finish and are excellently machined. Simply spin it as normal and watch it suddenly flip over and then continue to spin upside-down.



Ferrofluid is a runny fluid that is magnetic. Hold a magnet to it and watch how it reacts. Some of the shapes you can create are mesmerizing.

"If I do my job properly, it will make a tremendous difference to people's lives"

ScienceGrrl's (@Science_Grrl) founder explains to Helen Pilcher why girls don't feel valued for their intellect – and what she's doing to change this

A few years ago, I found myself wondering why women are so under-represented in science. It led me to set up ScienceGrrl, an organisation that celebrates and supports women in science. It was established in 2012 and is about raising the profile of female scientists and engineers so they can inspire the next generation.

A heartbreaking survey from 2013 suggested that girls feel valued more for their looks than for their intellect, and that if they voice their opinions they feel vulnerable. Add to this that science unfortunately has the perceived image of being intellectual and inaccessible. We're trying to challenge all these assumptions.

There was a time when I thought about becoming a professional musician. I have a grade eight in cello. But then I realised that physics would be more likely to help me pay the bills than music would.

In nuclear medicine, we inject people with radioactive stuff and watch where it goes. It's my job to make sure the cameras churn out consistently excellent images that doctors can rely upon to make decisions. Every day I walk past a waiting room full of people and think that if I do my job properly, it will make a tremendous difference to their lives. It's incredibly satisfying.

I first came across the concept of medical imaging in a physics lesson when I was at school. I knew from the age of 16 this was something I wanted to do as a career.

I've always been curious about the world around me. My parents tell me that when we went out for walks out in the countryside, I'd be the one staring at a beetle or buttercup and going 'ooh'.

When I want to unwind I put my boots on and go out walking in the Peak District. There's a sense of perspective to be had from how big and permanent the landscape is, and how small and transient we are. It helps keep me grounded.

I wish that we understood dementia better. As people live for longer, dementia is becoming even more of health priority, but we're still only scratching the surface when it comes to understanding exactly what is happening in the brain.



We have some new scanners coming and I'm going to be involved in projects to image the brains of people with dementia. It's a real privilege.

Home is the best place in the world. I love being curled up on the sofa with my two boys reading them stories. It's the best end to the day you could have.

Bad habits? I don't do enough exercise. My children really like eating sweets and chocolate and unfortunately so do I! **F**

Heather Williams is a senior medical physicist for nuclear medicine at the University of Manchester.

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